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INFRARED PHOTOMETRY, BOLOMETRIC LUMINOSITIES, AND EFFECTIVE TEMPERATURES FOR GIANT STARS IN 26 GLOBULAR CLUSTERS

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ABSTRACT

Infrared observations of 307 giant stars in 26 globular clusters are presented. The effects of H_2O absorption on the infrared colors are examined. The color-color correlations and color-magnitude diagrams, derived using an internally consistent set of distance moduli and reddenings, identify specific clusters with problematical reddenings or low quality optical data. The mean behavior of the color-color relationships is, in all cases, in good agreement with our earlier work.

Subject headings: clusters: globular — infrared: sources — photometry — stars: late-type — stars: luminosities

I. INTRODUCTION

This paper presents infrared photometric data for 307 giant stars in 26 galactic globular clusters. Initially, we concentrated on 10 clusters as a supplement to our previously published work (Cohen, Frogel, Persson 1978, hereafter GC1; Persson *et al.* 1980, hereafter GC3; Frogel, Persson, and Cohen 1981*a*, hereafter GC5). It subsequently became apparent that in order to study properly some of our new findings reported in Frogel (1980) and Frogel, Persson, and Cohen (1981*b*), an even larger cluster sample was needed, and we added 16 more clusters to our program.

The results of this work are presented in two papers. In addition to a presentation and discussion of the data (§§ II and III), this first paper gives those results which depend directly on the behavior of the colors and indices of individual stars. Section IV contains a reexamination of various color-color relations for cluster giants and the effects of H_2O absorption on these colors. In § V we assess critically the various techniques employed to obtain effective temperatures and luminosities and comment on mean color-color relations for field stars (adopted from Frogel *et al.* 1978, hereafter FPAM) which are needed for comparison with the globular cluster data. In § VI we present some characteristic H-R diagrams for the best observed clusters or clusters whose metal abundance has been the subject of some controversy. A second paper (Frogel, Cohen, and Persson 1983, hereafter GC9) contains an analysis of the implications of the data presented here for the globular cluster system as a whole.

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II. THE DATA

The infrared data were obtained in a similar manner and with the same photometric systems used to make the observations for all of our previous papers on globular cluster giants. Thirty-four cluster stars (this paper, GC5, and unpublished data for M67 and NGC 2204) with $J-K$ between 0.6 and 1.2 have been observed at both CTIO and Las Campanas. The mean differences and dispersions for a single pair of measurements are given in Table 1; there is no dependence of the differences on color. The dispersions are what would be expected from the uncertainties in a single measurement and are of the same size or less than the smallest found when different sets of optical data for the same cluster stars are compared. Twenty-one stars for which we present data here, in GC1, and in Frogel, Persson, and Cohen (1979, hereafter GC2) have also been observed by Pilachowski (1978). The mean difference in the K magnitudes is $K_{\rm FPC} - K_{\rm P} = -0.01$, with a dispersion of ± 0.04. Differences between the CO indices measured by Pilachowski and by us are large and systematic because of the different filter systems employed.

TABLE 1

A Comparison of the Las Campanas and CTIO Observations

Quantity	$\Delta(K)$	$\Delta(J-K)$	$\Delta(H-K)$	$\Delta(H_2O)$	$\Delta(CO)$
Mean	−0.013	+0.005	−0.008	−0.007	+0.000
Dispersion ...	+0.021	+0.025	+0.018	+0.022	+0.018
N	34	34	34	21	30

Note.—The symbol Δ is in the sense (LC)−(CTIO).

TABLE 2

NGC 288 Photometry

Star	Observed[a]			Reddening Corrected[b]								n	Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO		
C19	12.36(4)	0.60(5)	0.08(4)	12.35	1.40	0.97	2.31	0.59	0.08	...	...	1	1
C20	9.75	0.87	0.12	9.74	2.74	1.34	3.22	0.86	0.12	0.035	0.045	3	1
C23	12.57(3)	0.64(4)	0.09(3)	12.56	1.44	0.92	2.29	0.63	0.09	...	...	1	1
C32	13.13	0.61(3)	0.08(3)	13.12	1.27	0.83	2.22	0.60	0.08	...	...	2	1
C33	11.32	0.67(3)	0.09	11.31	1.90	1.19	2.66	0.66	0.09	...	...	1	1
C36	11.12	0.71	0.09	11.11	1.93	1.11	2.69	0.70	0.09	0.03	0.035	2	1
A77	10.02	0.84	0.12	10.01	...	1.38	3.00	0.83	0.12	0.06	0.065	2	2
A78	9.65	0.88(3)	0.14	9.64	...	1.46	3.17	0.87	0.14	0.035(3)	0.09	1	2
A80	11.23	0.70(4)	0.08	11.22	...	1.16	2.57	0.69	0.08	...	0.06 (3)	1	2
A96	9.32	0.91	0.13	9.31	...	1.56	3.31	0.90	0.13	0.05	0.11	2	2
A194	10.07	0.82(3)	0.12	10.06	...	1.34	2.93	0.81	0.12	...	0.06	1	2
A231	10.82	0.76	0.10	10.81	...	1.16	2.65	0.75	0.10	0.10	0.075	1	2
A245	10.53	0.75(3)	0.10	10.52	...	1.26	2.77	0.74	0.10	0.08	0.07	1	2
A260	8.48	0.98	0.18	8.47	...	1.87	3.97	0.97	0.18	0.115	0.12	3	2, 3, V1

[a]Numbers in parentheses are uncertainties in K, $J-K$, $H-K$, H_2O, and CO in units of hundredths of a magnitude when greater than 2.

[b]$E(B-V)=0.02$; mean of Harris and Racine 1979 and Zinn 1980.

Notes.—(1) Identification and photoelectric photometry from Cannon 1974. (2) Identification and photographic photometry from Alcaino 1975. (3) Semiregular variable with period of 103 d (Hogg 1973).

The new data are presented in Tables 2–27. Some of the NGC 5904 observations and all of the NGC 7078 observations were made with the 5 m Hale Reflector on Palomar Mountain. Data for stars in NGC 288, 362, 5904, 6637, and 6656 were obtained with the 2.5 m du Pont Reflector on Cerro Las Campanas and with the CTIO 4 m reflector; a considerable number of these stars were observed on both telescopes. Columns labeled n in the tables give the number of nights on which a star was observed. All of the remaining data were obtained with the 4 and 1.5 m CTIO telescopes. Magnitudes, colors, and indices have been reduced to the CIT/CTIO standard system as defined by Elias *et al.* (1982). This is the same system used for our previous papers.

Effective temperatures and bolometric luminosities, derived as explained in GC5 and in § V of this paper, are given in Table 28. Multiple observations for a number of the cluster variable stars are given in supplemental tables appended to the main ones; these data are discussed in Frogel (1983). Sources for the optical photometry, values used for the distance moduli, questions of membership, etc., are contained in the notes to the tables. An asymptotic giant branch (AGB) designation for a star is based solely on the optical data and is thus dependent on the quality of the optical data.

Values for $E(B-V)$ are taken from Zinn (1980) or Harris and Racine (1979). These two sets of reddening determinations are in close agreement. For the distance

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TABLE 3

NGC 362 PHOTOMETRY

Star[a]	Observed[b] K	J−K	H−K	Reddening Corrected[c] K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	n	Notes
I-2	11.59(3)	0.69(4)	0.11(3)	11.58	1.63	1.01	2.54	0.67	0.10	...	...	1	1
I-23	10.43	0.80(3)	0.11	10.42	2.23	1.21	2.88	0.78	0.10	...	0.01	1	1
I-44	10.09	0.81(3)	0.13	10.08	2.62	1.30	2.89	0.79	0.12	...	0.025	1	1
I-52	12.41(3)	0.64(3)	0.06(3)	12.40	1.07	0.68	2.50	0.62	0.05	...	...	1	1
II-20	9.31	0.89	0.14	9.30	3.03	1.48	3.43	0.87	0.13	0.05	0.11	2	1
II-40	12.36	0.65(4)	0.09	12.35	1.31	0.90	2.36	0.63	0.08	...	...	1	1
II-43	11.16	0.68(3)	0.09	11.15	1.58	0.95	2.46	0.66	0.08	0.09(3)	0.045(3)	1	1
II-47	11.75(3)	0.59(3)	0.10	11.74	1.38	0.85	2.34	0.57	0.09	...	...	2	1
II-49	11.14	0.69(3)	0.10	11.13	1.81	1.07	2.70	0.67	0.09	...	...	1	1
III-4	10.67	0.78(3)	0.15	10.66	2.08	1.16	2.88	0.76	0.14	0.04	0.065	1	1
III-11	8.72	0.95(3)	0.17	8.71	3.78	1.66	3.69	0.93	0.16	0.065	0.12	1	1
III-25	10.62	0.75(3)	0.10	10.61	2.18	1.18	2.77	0.73	0.09	0.035	0.06	1	1
III-37	10.11	0.79	0.12	10.10	2.54	1.27	2.85	0.77	0.11	0.005	0.08	2	1
III-39	9.06	0.87	0.15	9.05	3.16	1.56	3.40	0.85	0.14	0.04	0.06	4	1
III-44	9.34	0.91	0.14	9.33	3.08	1.47	3.36	0.89	0.13	0.08	0.06	2	1
III-63	9.02	0.94(3)	0.15	9.01	3.48	1.61	3.57	0.92	0.14	0.035	0.09	1	1
III-70	9.53	0.81	0.14	9.52	2.68	1.34	3.13	0.79	0.13	0.03	0.01	1	2
IV-84	9.57	0.83	0.14	9.56	2.97	1.45	3.34	0.81	0.13	0.04	0.025	3	1
IV-91	10.56	0.70	0.11	10.55	2.22	1.17	2.75	0.68	0.10	0.095	0.045	2	1, 4
IV-100	9.00	0.91(3)	0.14	8.99	3.50	1.65	3.68	0.89	0.13	0.055	0.08	1	1
V2	8.65	0.97(3)	0.23	8.64	3.3	1.6	3.9	0.95	0.22	0.035	0.03	1	3

[a]Identification numbers are from Menzies 1967.

[b]Numbers in parentheses are uncertainties in K, $J - K$, $H - K$, H_2O, and CO in units of hundredths of a magnitude when greater than 2.

[c]$E(B - V) = 0.04$ (Harris and Racine 1979; Zinn 1980).

NOTES.—(1) Photographic photometry from Harris 1982. (2) Photoelectric photometry from Harris 1982. (3) Mean optical data from Eggen 1972, Table 22. (4) Red dwarf (McClure and Norris 1974). (5) Lack of agreement for this red star among *BV* values given by Harris 1982, Eggen 1972, and Menzies 1967 suggests that it may be variable. Values used are means of those given by Harris and Eggen; the latter values have been adjusted as recommended by Harris.

TABLE 4

PHOTOMETRY OF NGC 1261

Star[a]	Observed K	J−K	H−K	Reddening Corrected[b] K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	Notes
3	10.27	0.92(3)	0.13	10.27	3.05	1.55	3.55	0.91	0.13	...	...	3
9	9.83	1.01	0.19	9.83	3.22	1.68	3.51	1.00	0.19	...	0.11	1, 3
10	10.19	0.92(3)	0.14	10.19	3.06	1.55	3.53	0.91	0.14	...	...	3
11	11.09	0.86(3)	0.14	11.09	...	1.35	3.18	0.85	0.14	...	...	3
52	10.72(3)	0.83(3)	0.13	10.72	...	1.24	3.11	0.82	0.13	...	...	4
81	10.64(3)	0.86(3)	0.13	10.64	...	1.39	2.99	0.85	0.13	...	...	4
IR-1	9.87(4)	0.99	0.19	9.87	...	...	...	0.98	0.19	...	...	2

[a]Identification numbers are from Alcaino and Contreras 1971, except as noted.

[b]$E(B - V) = 0.01$; mean of Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) Observed twice. (2) Only bright, red star found by scanning cluster center at K. (3) Photoelectric photometry from Alcaino and Contreras 1971. (4) Photographic photometry from Alcaino and Contreras 1971.

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TABLE 5

PHOTOMETRY OF NGC 1851

Star[a]	Observed[a] K	J-K	H-K	Reddening Corrected[b] K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	Notes
3	10.30	0.86(3)	0.13	10.29	...	1.38	3.24	0.85	0.13	...	...	A-12, 6
95	10.12	0.88(3)	0.14	10.11	...	1.42	3.41	0.87	0.14	...	...	A-E, 5
112	10.39	0.90(3)	0.13	10.38	...	1.46	3.37	0.89	0.13	...	...	A-F, 5
151	10.51	0.81(3)	0.09	10.50	...	1.35	3.14	0.80	0.09	...	...	A-52, 6
168	9.33(3)	0.95(4)	0.14	9.32	...	1.69	3.83	0.94	0.14	...	0.10	(≡V24), 5, 7
262	9.76	0.91	0.13	9.75	...	1.55	3.48	0.90	0.13	...	0.13(3)	A-109, 1, 6
279	10.80	0.79(3)	0.11	10.79	...	1.28	3.06	0.78	0.11	...	...	A-114, 6
294	9.72	0.93	0.15	9.71	...	1.59	3.62	0.92	0.14	...	0.08	A-117, 2, 6
333	10.87	0.82	0.12	10.86	...	1.28	3.08	0.81	0.11	...	...	A-151, 5
IR-1	9.12(3)	1.00(4)	0.16	9.11	...	...	...	0.99	0.15	...	0.06	3
IR- 4	9.11(4)	0.98(4)	0.17	9.10	...	...	...	0.97	0.16	...	0.07	3
IR-11	8.49(4)	0.93(4)	0.16	8.48	...	...	...	0.92	0.15	...	0.115	3, 4

[a]Identifications in this column are from Stetson 1981 unless otherwise noted. Numbers and letters preceded by an "A" in the "Notes" column are from Alcaino 1976*a*.
[b]$E(B-V)_0 = 0.02$ (Stetson 1981).

NOTES.—(1) Measured twice. (2) Measured 3 times. (3) Bright red stars found by scanning at *K*. (4) Two stars of nearly equal brightness and color were measured together. Therefore, for purposes of plotting, $K_0 = 9.18$ will be used. Also M_{bol} in Table 29 will have been made fainter by 0.7 mag. (5) Photoelectric *BV* (Stetson 1981). (6) Photographic *BV* (Stetson 1981). (7) Period = 183(?)d according to Wehlau *et al.* 1982.

TABLE 6

PHOTOMETRY OF NGC 1904 (M79)

Star[a]	Observed Values[b] K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	Notes[c]
35	9.83(3)	3.36	1.52	3.36	0.85	0.13	...	...	2, SH223
41	10.00(3)	2.94	1.40	3.10	0.79	0.14	...	...	(≡V2), 3, SH202
50	10.56(3)	2.60	1.29	3.05	0.80	0.11	...	...	2, SH131
51	10.31(3)	2.81	1.36	3.13	0.80	0.11	...	...	2, SH153
53	9.63(3)	3.26	1.52	3.40	0.85	0.14	...	0.06	3, SH160
81	10.18(3)	2.98	1.40	3.22	0.81	0.12	...	...	3, SH68
IR-1	9.87(3)	...	...	...	0.82	0.12	...	...	1
IR-5	10.01(3)	3.07	1.50	3.21	0.82	0.12	...	...	1, 2, SH15
IR-7	9.87(3)	...	...	...	0.87	0.13	...	...	1
IR-8	9.88(3)	...	...	...	0.86	0.12	...	...	1

[a]Identification from Alcaino 1976*b*, except when noted.
[b]$E(B-V)_0 = 0.00$ (Harris and Racine 1979; Zinn 1980).
[c]The numbers given by Stetson and Harris 1977 are preceded by an "SH."

NOTES.—(1) These are bright, red stars found by scanning at *K*. (2) Photographic *UBV* photometry from Stetson and Harris 1977. (3) Average of photoelectric and photographic *UBV* photometry from Stetson and Harris 1977.

TABLE 7

PHOTOMETRY OF NGC 2298

Star[a]	Observed			Reddening Corrected[b]						Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	
7	10.21	0.82	0.15	10.17	...	1.20	2.89	0.75	0.12	2
8	10.19	0.81	0.15	10.15	...	1.21	2.88	0.74	0.12	2
9	10.73	0.81	0.16	10.69	...	1.14	2.87	0.74	0.13	2
11	10.85	0.68	0.12	10.81	...	1.16	2.52	0.61	0.09	2
31	10.76	0.78(3)	0.14	10.72	...	1.09	2.71	0.71	0.11	2
IR-1	9.86	0.89	0.17	9.82	...	...	...	0.82	0.14	1

[a]Identification from Alcaino 1974*a*, except as noted.
[b]$E(B - V)_0 = 0.13$ (a mean of Harris and Racine 1979 and Zinn 1980).

NOTES.—(1) Only bright, red star found by scanning at *K*. (2) Photographic *BV* photometry from Alcaino 1974*a*.

TABLE 8

PHOTOMETRY OF NGC 2808

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	
11	9.28	1.05(3)	0.18	9.22	...	1.61	3.52	0.93	0.13	0.05(4)	0.05	3
13	9.91	0.89(3)	0.17	9.85	...	1.52	2.66	0.77	0.12	...	0.045	3
14	9.09	1.04(3)	0.19	9.03	...	1.73	3.32	0.92	0.14	...	0.135	3
15	8.77	1.12(3)	0.30	8.71	...	1.80	3.88	1.00	0.25	0.36(4)	0.095	3
19	9.11	1.03(3)	0.18	9.05	...	1.67	3.24	0.91	0.13	0.04(3)	0.125	3
20	9.29	1.00(3)	0.17	9.23	...	1.49	3.05	0.88	0.12	0.04(4)	0.135	3
22	9.66	1.01	0.16	9.60	...	1.43	3.35	0.89	0.11	...	...	H332, 1
39	9.81	0.91	0.17	9.75	2.82	1.37	3.13	0.79	0.12	...	...	H120, 2
65	9.02	1.05(3)	0.20	8.96	...	1.74	3.43	0.93	0.15	0.08(4)	0.105	3
82	9.90(3)	0.88	0.13	9.84	...	1.42	2.50	0.76	0.08	...	...	3
87	9.51(3)	1.04	0.17	9.45	...	1.58	3.16	0.92	0.12	...	...	3
204	9.73	1.02	0.17	9.67	3.05	1.47	3.35	0.90	0.12	...	...	H275, 2

[a]Identification from Alcaino 1971*b*. Numbers preceded by an "H" in the "Notes" column are identified by Harris 1975.
[b]$E(B - V)_0 = 0.22$ (Harris and Racine 1979; Zinn 1980).

NOTES.—(1) Photographic *BV* photometry from Harris 1975. (2) Photoelectric *UBV* photometry from Harris 1978. (3) Photographic *BV* photometry from Alcaino 1971*b* with *V* magnitudes adjusted by −0.1 suggested by Fig. 3 of Harris 1975.

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TABLE 9

PHOTOMETRY OF NGC 4372

Star[a]	Observed			Corrected Reddening[b]								Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO	
1	7.79	1.00	0.22	7.66	3.00	1.36	3.26	0.75	0.13	...	0.085	1, 4
2	7.96	0.96	0.20	7.83	2.74	1.38	3.16	0.71	0.11	...	0.015	1
2002	8.52	0.92	0.18	8.39	...	1.41	2.80	0.67	0.09	...	0.015	2
2017	7.19	1.07	0.22	7.06	...	1.41	3.48	0.82	0.13	0.04	0.155	A-104, 2, 3
2063	8.17	0.93	0.20	8.04	...	1.20	2.92	0.68	0.11	...	0.035	A-97, 2
2121	8.74	0.95	0.19	8.61	...	1.14	2.91	0.70	0.10	...	0.005	A-141, 2
3010	8.77	0.91	0.19	8.64	...	1.30	2.58	0.66	0.10	...	-0.005	A-20, 2
3033	8.25	0.96	0.22	8.12	...	1.35	3.02	0.71	0.13	...	0.025	A-13, 2
3035	9.02	0.83	0.18	8.89	...	1.35	2.35	0.58	0.09	...	0.105	A-D, 2, 3
4002	6.63	1.19	0.26	6.50	...	1.42	4.35	0.94	0.17	0.05	0.205	A-B, 2, 3

[a] Identification from Hartwick and Hesser 1973. Corresponding numbers from Alcaino 1974*b* are given in the "Notes" column preceded by an "A." Note that N and S are reversed on Alcaino's chart.

[b] $E(B - V)_0 = 0.45$ from Harris and Racine 1979. Hartwick and Hesser 1973 note that the reddening is variable across the cluster.

NOTES.—(1) Photoelectric *UBV* values from Hartwick and Hesser 1973. (2) Photographic *BV* values from Hartwick and Hesser 1973. (3) Very strong CO; probable superposed field giant. (4) Moderately strong CO; lies far from cluster; membership questionable.

TABLE 10

PHOTOMETRY OF NGC 4590 (M68)

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO	
A- 14	9.55	0.77(3)	0.13	9.54	...	1.40	3.01	0.76	0.13	...	0.005	2
I- 82	9.53	0.77(3)	0.13	9.52	...	1.31	3.00	0.76	0.13	...	0.00	A-62, 3
I-144	9.88	0.78(3)	0.15	9.87	...	1.27	2.86	0.77	0.15	...	0.005	A-53, 3
I-256	9.81	0.75(3)	0.13	9.80	...	1.32	2.77	0.74	0.13	...	0.02	A-97, 3
I-260	9.52(3)	0.75	0.13	9.51	...	1.26	2.94	0.74	0.13	...	...	3
G	8.27	0.85(3)	0.15	8.26	...	2.06	4.05	0.84	0.15	0.21(4)	0.13	A-45, 4
ZNG2	9.73	0.71	0.11	9.72	...	1.13	2.70	0.70	0.11	...	...	1, 3

[a] Identifications here and in the "Notes" column preceded by an "A" from Alcaino 1977. All others from Harris 1975.

[b] $E(B - V)_0 = 0.02$ is a mean from Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) An ultraviolet bright star according to Zinn, Newell, and Gibson 1972. (2) Photographic *BV* values from Alcaino 1977. (3) Photographic *BV* values from Harris 1975. (4) Photoelectric *BV* values from Harris 1975. Probably a field star, but H_2O and CO indices are inconsistent with either a dwarf or giant star. Note very red $B - V$. Is it a variable?

TABLE 11

PHOTOMETRY OF NGC 4833

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	
MA1	8.36(3)	0.93	0.17	8.26	2.62	1.33	3.02	0.73	0.09	...	0.02	3
MA18	8.23	0.97	0.18	8.13	3.21	1.43	3.15	0.77	0.10	...	0.14	4, 7
MA75	8.20	0.96	0.20	8.10	2.98	1.49	3.39	0.76	0.12	...	0.01	4
MA100	8.63	1.21(4)	0.29	6.53	3.19	1.53	5.33	1.01	0.21	0.09(6)	0.24	1, 2, 4
B55	8.24(3)	0.96	0.20	8.14	2.89	1.48	3.20	0.76	0.12	...	0.01	A82, 4
B172	8.63(3)	0.89	0.17	8.53	2.45	1.29	2.93	0.69	0.09	...	0.04	A1, 4
C81	8.71(3)	0.92	0.19	8.61	2.52	1.32	2.97	0.72	0.11	...	0.015	A79, 4
D75	8.34(3)	0.97	0.20	8.24	...	1.29	3.11	0.77	0.12	...	-0.02	A260, 4
V16	8.52(3)	0.91	0.20	8.42	2.36	1.19	3.07	0.71	0.12	...	-0.03	5
V9	8.20(3)	0.84	0.17	8.10	...	1.64	2.96	0.64	0.09	0.01	0.00	A228, 6

[a]Identifications here and in the "Notes" column are from Menzies 1972 and Alcaino 1971*a*. To avoid confusion, stars from ring A of Menzies are preceded by an "MA" while those for Alcaino by an "A."

[b]$E(B-V)_0 = 0.36$: an average of Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) Observed $K - L = 0.18 \pm 0.04$; $(K - L)_0 = 0.13$. (2) Field star; lies below giant branch in a *V*, *B-V* diagram; very red colors and very strong CO. (3) Photoelectric *UBV* from Menzies 1972. (4) Photographic *UBV* from Menzies 1972. (5) According to Menzies 1972, this star may be a small-amplitude irregular or semiregular variable. His mean *UBV* values are given. (6) Photographic *UBV* from Alcaino 1971*a*. (7) Probably a field star; strong CO, red $U - V$; lies in Menzies's 1972 outer annulus.

TABLE 12

PHOTOMETRY OF NGC 5024 (M53)

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	
G	10.95	0.77	0.12	10.94	...	1.39	3.07	0.75	0.11	...	...	3
K	10.43	0.81	0.14	10.42	...	1.55	3.26	0.79	0.13	0.05	0.015	V50, 2, 3
1-2- 8	10.98	0.75	0.12	10.97	...	1.35	2.98	0.73	0.11	...	...	3
1-2-18	10.72	0.77	0.13	10.71	...	1.46	3.11	0.75	0.12	...	...	3
4-4-16	11.00	0.75	0.12	10.99	...	1.30	3.00	0.73	0.11	...	...	V49, 2, 3
1-6- 5	10.71	0.82	0.12	10.70	...	1.35	3.13	0.80	0.11	...	...	3
3-6- 4	10.58	0.76	0.12	10.57	...	1.58	3.18	0.74	0.11	...	0.015	3
IR- 1	10.61(6)	0.76	0.10	10.60	...	...	...	0.74	0.09	...	...	1

[a]Identifications are from Cuffey 1965, except as noted.

[b]$E(B-V)_0 = 0.03$ is an average of values given by Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) This is brightest red star found at *K* in cluster center. (2) Small-amplitude variable according to Cuffey 1965. Variable designation is as given by Hogg 1973. (3) Photographic photometry from Cuffey 1965.

TABLE 13

PHOTOMETRY OF NGC 5286

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO	
4	9.76	0.91(4)	0.18	9.69	...	1.28	3.15	0.77	0.13	...	...	1
49	9.83	0.88(4)	0.16	9.76	...	1.27	3.04	0.74	0.11	...	...	H95, 2
50	9.83	0.86	0.17	9.76	...	1.29	2.92	0.72	0.12	...	0.04	H55, 2
97	9.34	0.94	0.18	9.27	...	1.38	3.09	0.80	0.13	...	0.06	1
101	9.91	0.90	0.17	9.84	...	1.37	2.86	0.76	0.12	...	0.05	1
107	9.58	0.91	0.18	9.51	...	1.49	3.09	0.77	0.13	...	0.17	1, 3

[a]Identifications in this column are from Alcaino 1974*c*. Corresponding numbers from Harris, Racine, and de Roux 1976 are given in the "Notes" column preceded by an "H."

[b]$E(B-V)_0 = 0.25$, a mean of Harris and Racine 1979 and Zinn 1980, was used. The observed H_2O and CO values were corrected by -0.01 and $+0.01$, respectively.

NOTES.—(1) Photographic *BV* from Alcaino 1974*c*, with $B - V$ shifted by -0.2 to agree with Harris, Racine, and de Roux 1976. (2) Photographic *BV* photometry from Harris, Racine, and de Roux 1976. (3) Probable field star because of strong CO.

TABLE 14

PHOTOMETRY OF NGC 5897

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO	
9	10.00	0.84	0.16	9.98	...	1.47	3.18	0.81	0.15	...	0.025	1
160	10.29	0.81	0.14	10.27	...	1.38	2.97	0.78	0.13	...	0.015	1
209	10.48(3)	0.79	0.13	10.46	...	1.43	3.09	0.76	0.12	...	...	1
255	9.70	0.86	0.15	9.68	...	1.75	3.53	0.83	0.14	...	0.04	1
263	9.65	0.87	0.16	9.63	...	1.68	3.44	0.84	0.15	...	0.035	1
V5	9.78	0.87	0.17	9.76	...	1.57	3.33	0.84	0.16	0.07(3)	0.015	1

[a]Identifications are from Sandage and Katem 1968.

[b]$E(B-V)_0 = 0.06$ (Harris and Racine 1979).

NOTES.—(1) *BV* photographic photometry from Sandage and Katem 1968.

moduli we utilized the compilation of V_{HB} given by Harris and Racine (1979), with M_{V_0} values for the horizontal branch adopted as $+0.6$ for the clusters with metallicities on Zinn's (1980) scale of $[Fe/H]_Z < -1.0$, $+0.7$ for $-1.0 \le [Fe/H]_Z < -0.8$, and $+0.8$ for $[Fe/H]_Z \ge -0.8$. The rationale for this choice of horizontal-branch luminosity and the effects of changes to these values are dealt with in GC9. The adopted reddenings and distance moduli are listed in Tables 2–28.

III. SELECTION OF STARS

a) *Sources*

For each of the 26 newly observed globular clusters we give brief remarks concerning the sources of the optical photometry and the criteria by which we selected the stars to be observed in the infrared.

i) *NGC 288*

For 45 stars in common between Alcaino (1975) and Cannon (1974), the mean differences are $V_C - V_A = +0.015 \pm 0.06$ and $(B-V)_C - (B-V)_A = -0.02 \pm 0.09$. Essentially all of the brightest stars in Table 2 have photometry only from Alcaino and are from the inner part of the cluster. All of the bright, red giants from Cannon and Alcaino's lists were observed in the infrared.

ii) *NGC 362*

Harris (1982) gives a full discussion of earlier photometric studies of this cluster. The stars with infrared

TABLE 15

M5 (NGC 5904) PHOTOMETRY

Star[a]	Observed[b] K	J-K	H-K	Reddening Corrected[c] K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	n	Notes
I-1	12.09(3)	0.53(3)	0.12(3)	12.08	...	0.74	2.07	0.52	0.11	...	...	1	1,3
I-4	10.56(3)	0.73(3)	0.11(3)	10.55	...	1.09	2.78	0.72	0.10	...	0.025	1	3
I-14	9.95(3)	0.79(3)	0.10(3)	9.94	...	1.23	2.98	0.78	0.09	0.06	0.075	1	3
I-20	9.39(3)	0.82(3)	0.16(3)	9.38	...	1.42	3.04	0.81	0.15	...	0.08	1	3
I-25	10.84(3)	0.71(3)	0.12(3)	10.83	...	1.06	2.70	0.70	0.11	...	0.04	1	2
I-55	11.20	0.61	0.11	11.19	...	0.89	2.38	0.60	0.10	...	-0.005	2	1,3
I-61	10.51(3)	0.72(3)	0.08(3)	10.50	...	1.14	2.78	0.71	0.07	0.085	0.065	1	3
I-67	11.82(3)	0.52(3)	0.06(3)	11.81	...	0.76	2.11	0.51	0.05	...	...	1	1,3
I-68	9.07	0.86	0.12	9.06	...	1.50	3.24	0.85	0.11	0.055	0.105	2	3
II-9	9.30	0.83	0.11	9.29	...	1.50	2.95	0.82	0.10	0.045	0.065	8	3
II-50	11.20(3)	0.69(3)	0.09(3)	11.19	...	0.96	2.73	0.68	0.08	...	...	1	3
II-51	11.44(3)	0.62(3)	0.06(3)	11.43	...	0.94	2.53	0.61	0.05	...	-0.02	1	3
III-3	9.03	0.86	0.12	9.02	...	1.46	3.26	0.85	0.11	0.05	0.095	3	3
III-16	12.00(4)	0.52(3)	0.07(3)	11.99	...	0.70	2.16	0.51	0.06	...	...	1	1
III-36	9.69	0.81	0.11	9.68	...	1.31	3.01	0.80	0.10	...	0.05	2	3
III-53	11.06	0.63	0.10	11.05	...	0.86	2.41	0.62	0.09	...	0.015	2	1
III-56	10.75	0.65	0.08	10.74	...	0.96	2.52	0.64	0.07	...	0.005	2	1,3
III-78	9.37(3)	0.83(3)	0.11(3)	9.36	...	1.38	3.14	0.82	0.10	...	0.085	1	3
IV-3	12.72(4)	0.57(3)	0.08(3)	12.71	...	0.78	2.24	0.56	0.07	...	...	1	3
IV-19	9.34	0.82	0.11	9.33	...	1.36	3.18	0.81	0.10	0.045	0.085	2	3
IV-28	11.86(3)	0.65(3)	0.13(3)	11.85	...	0.91	2.51	0.64	0.12	...	...	1	3
IV-47	9.00(3)	0.89(3)	0.13(3)	8.99	...	1.48	3.28	0.88	0.11	...	0.09	1	3
IV-59	9.66	0.76	0.09	9.65	...	1.34	2.91	0.75	0.08	0.05	0.08	2	3
IV-81	8.62	0.90	0.14	8.61	...	1.58	3.45	0.89	0.13	0.05	0.08	3	4
IV-86	13.26(6)	0.37(5)	-0.03(5)	13.25	...	0.58	1.64	0.36	-0.04	...	...	1	1,3

[a]Identification numbers are from Arp 1962.

[b]Numbers in parenthesis are uncertainties in K, $J-K$, $H-K$, H_2O, and CO in units of hundredths of a magnitude when greater than 2.

[c]The V, $B-V$ values are an average of the photographic values of Buonanno, Corsi, and Fusi Pecci 1981, and Simoda and Tanikawa 1970. $E(B-V) = 0.03$ (Harris and Racine 1979; Zinn 1980).

NOTES.—(1) AGB star on basis of location in V, $B-V$ diagram. (2) A correction of -0.03 was applied to the K magnitude because of confusion with a faint star. (3) Proper motion member (Cudworth 1979). (4) Radial velocity member (Cohen, unpublished data).

data include essentially all of the bright red stars from Menzies (1967) and Alcaino (1976*c*), as well as a selection of fainter giants.

iii) *NGC 1261*

The V, $B-V$ diagram of Alcaino and Contreras (1971) shows considerable scatter. All stars with $V<14$ or $B-V>1.4$ were selected for observation.

iv) *NGC 1851*

Six of the brightest and reddest stars from Alcaino (1976*a*) were observed, as well as two of his photoelectric sequence stars which may be giants. Stetson's (1981) photometry became available after the infrared observations were completed.

v) *NGC 1904*

The V, $B-V$ data of Alcaino (1976*b*) shows a well-defined giant branch. All stars with $B-V>1.3$ were selected for observation. Stetson and Harris's (1977) photometry was used for the final analysis.

vi) *NGC 2298*

All stars with $V<14$ or $B-V>1.2$ from Alcaino (1974*a*) were observed.

vii) *NGC 2808*

The brightest and reddest stars from the lists of Alcaino (1971*b*) and Harris (1975) were observed in the infrared. There may be some problems with the optical data (see § VI here and § III*a* of GC9).

TABLE 16

PHOTOMETRY OF NGC 5927

Star[a]	Observed K	Observed J-K	Observed H-K	Reddening Observed[b] K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO	Notes
23	11.02	1.02	0.20	10.89	2.56	1.37	2.97	0.76	0.10	...	...	2
100	7.90	1.28	0.30	7.77	3.04	1.56	5.09	1.02	0.20	0.10	0.24	2
157	11.20(3)	1.04	0.21	11.07	2.46	1.41	3.09	0.78	0.11	...	0.17	2
532	9.47(3)	1.20	0.24	9.34	3.16	1.53	3.84	0.94	0.14	0.05	0.185	2
536	10.68	1.05	0.20	10.55	2.69	1.39	3.23	0.79	0.10	0.04	0.195	2
563	11.85	0.94	0.17	11.72	2.10	1.25	2.74	0.68	0.07	...	...	2
587	11.84(3)	0.90	0.17	11.71	2.14	1.21	2.70	0.64	0.07	...	...	2
622	10.05(3)	1.11	0.21	9.92	3.28	1.57	3.45	0.85	0.11	0.04	0.12	2
627	8.91	1.27	0.26	8.78	3.18	1.56	4.61	1.01	0.16	0.10	0.175	2
799	8.65	1.28	0.34	8.52	3.54	1.81	4.75	1.02	0.24	0.18	0.21	2
857	11.44	1.00	0.20	11.31	2.47	1.33	2.94	0.74	0.10	...	...	2
LM 9	8.52	1.27	0.29	8.39	...	...	5.02	1.01	0.19	0.12	0.225	3
LM21	8.50	1.25	0.29	8.37	...	...	4.84	0.99	0.19	0.13	0.235	3
V3	7.08	1.30	0.42	6.95	...	...	~7	1.04	0.32	0.65	0.21	1, 5
V5	8.28	1.31	0.30	8.15	...	...	5.4	1.05	0.20	0.12	0.165	4
V6	8.55	1.27	0.27	8.42	...	...	5.3	1.01	0.17	0.07	0.16	4
V8	8.30(3)	1.28	0.32	8.17	...	...	5.8	1.02	0.22	0.11	0.20	4
V9	8.22	1.34	0.30	8.09	...	...	6.2	1.08	0.20	0.09	0.14	4

[a]Numbers without letters are from Menzies 1974. Those preceded by "LM" are from Lloyd-Evans and Menzies 1977. The "V" denotes variables from Hogg 1973.

[b]$E(B-V)_0 = 0.46$ is a mean of Kron and Guetter 1976 and Zinn 1980. Corrections of -0.02 and $+0.015$ were applied to the observed H_2O and CO values, respectively.

NOTES.—(1) $K - L = 0.57$; $(K - L)_0 = 0.51$. (2) Photographic *UBV* photometry from Menzies 1974. (3) Photographic *V* magnitude from Lloyd-Evans and Menzies 1977. (4) Lloyd-Evans and Menzies 1977 give the following values of V(max) and V(min) for these variables; the mean value was used to form $V - K$: *V*5, 14.7–15.2; *V*6, 14.8–15.4; *V*8, 15.0–15.8; *V*9, 15.3–16.2. (5) A long-period variables (p = 312d). *V* is estimated to have been ~15 at time of observations.

viii) *NGC 4372*

All stars with $B-V>1.6$ and $V<13$ were selected from Alcaino (1974*b*) for observation. In addition, all stars with $B-V>1.65$ were selected from Hartwick and Hesser (1973).

ix) *NGC 4590*

All stars with $B-V>1.2$ were selected from the lists of Harris (1975) and Alcaino (1977).

x) *NGC 4833*

The brightest and reddest stars from the lists of Alcaino (1971*a*) and Menzies (1972) were observed in the infrared.

xi) *NGC 5024*

All stars with $V<14.5$ or $B-V>1.3$ from the list of Cuffey (1965) were observed in the infrared.

xii) *NGC 5286*

Stars with $B-V>1.7$ from Alcaino (1974*c*) and with $B-V>1.4$ from Harris, Racine, and deRoux (1976) were selected for observation.

xiii) *NGC 5897*

All stars with $B-V>1.4$ from Sandage and Katem (1968) were measured in the infrared. The photoelectric observations of Eggen (1972) are systematically fainter in V and bluer in $B-V$, and were not used.

xiv) *NGC 5904*

The selection of bright, red stars was originally made from the list of Arp (1962) and included the half-dozen or so at the top of the giant branch. Since no significant differences were found in either the V magnitudes or the $B-V$ colors between the work of Simoda and Tanikawa (1970) and Buonanno, Corsi, and Fusi-Pecci (1981), these two sets of data were averaged together as noted in Table 15.

TABLE 17A

M4 (NGC 6121) PHOTOMETRY

Star[a]	Observed			Reddening Corrected[b]								n	Notes[c]
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO		
2206	7.80	0.97	0.19	7.70	2.20	1.13	3.10	0.77	0.12	...	0.08	1	1
3209	6.50	1.08	0.21	6.40	2.93	1.35	3.41	0.88	0.14	0.015	0.10	1	1, 8
2307	6.99	1.14	0.22	6.89	2.80	1.35	3.55	0.94	0.15	0.055	0.08	1	1, E316
3303	7.54	1.01	0.19	7.44	2.72	1.28	3.30	0.81	0.12	0.015	0.13	1	1, 10
1403	8.07	0.97	0.20	7.97	2.13	1.11	3.02	0.77	0.13	...	0.05	1	1
1411	6.39	1.14	0.23	6.29	3.03	1.43	3.68	0.94	0.16	0.045	0.085	1	1, E512
1412	5.89	0.88	0.23	5.79	2.6	1.28	3.3	0.68	0.16	0.05	-0.03	1	V4, 4, 6
2406	6.34	1.05	0.22	6.24	3.3	1.44	3.6	0.85	0.15	0.055	0.09	1	V13, 4, 7
3413	7.19	0.98	0.19	7.09	2.37	1.21	3.15	0.78	0.12	0.015	0.09	1	1
1514	5.80	1.15	0.24	5.70	3.00	1.55	4.05	0.95	0.17	0.065	0.135	1	3, E522
1605	8.50	0.91	0.19	8.40	...	1.08	2.92	0.71	0.12	...	0.03	1	2, E209
1608	9.65	0.85	0.19	9.55	...	0.98	2.52	0.65	0.12	...	...	1	2
1621	10.08	0.83	0.17	9.98	...	0.94	2.39	0.63	0.10	...	...	1	2
1622	9.88	0.82	0.16	9.78	...	0.96	2.49	0.62	0.09	...	...	1	2
2608	8.36	0.95	0.20	8.26	2.01	1.10	2.89	0.75	0.13	...	0.075	1	3, E6
2617	7.57	1.05	0.21	7.47	...	1.16	3.33	0.85	0.14	...	0.08	1	2
2623	9.35	0.88	0.18	9.25	...	1.01	2.58	0.68	0.11	...	0.035	1	2
2626	8.59	0.93	0.18	8.49	1.87	1.09	2.87	0.73	0.11	...	0.05	1	3, E154
3612	7.79	0.99	0.19	7.69	2.29	1.18	3.14	0.79	0.12	...	0.07	1	3, E74
3624	7.60	1.02	0.20	7.50	2.40	1.23	3.20	0.82	0.13	0.055	0.09	1	3, E27
4611	5.72	1.24	0.24	5.62	3.65	1.65	4.30	1.04	0.17	0.05	0.09	1	3, 9, E259
4613	5.72	1.22	0.24	5.62	3.42	1.61	4.09	1.02	0.17	0.06	0.11	1	3, 9, E261
4624	9.11	0.82	0.14	9.01	...	1.03	2.60	0.62	0.07	...	...	1	2
4630	8.21	0.96	0.19	8.11	2.03	1.12	3.02	0.76	0.12	...	0.085	1	3, E237
4633	7.98	0.91	0.19	7.88	1.88	1.09	2.91	0.71	0.12	...	0.07	1	3, E205
3713	6.36	1.15	0.24	6.26	...	1.39	3.85	0.95	0.17	0.045	0.10	1	2, 5

[a]Identification numbers are from Lee 1977.
[b]$E(B-V)_0 = 0.36$. This is an average of Harris and Racine 1979 and Zinn 1980.
[c]Numbers preceded by an "E" are from Eggen 1972 as given by Lee 1977.

NOTES.—(1) Photoelectric *UBV* photometry from Lee 1977. (2) Photographic *BV* photometry from Lee 1977. (3) Photographic *V* magnitudes from Lee 1977; photoelectric *UBV* colors from Eggen 1972. (4) Mean optical values for these variables from Eggen 1972, 1977. Infrared values are representative. Individual observations are given in Table 17B. (5) $(K-L)_0 = 0.11 \pm 0.04$. (6) $(K-L)_0 = 0.28 \pm 0.03$. (7) $(K-L)_0 = 0.19 \pm 0.03$. (8) $(K-L)_0 = 0.10 \pm 0.03$. (9) The radial velocities tabulated by Webbink 1981 are consistent with cluster membership for these two stars—the brightest and reddest in the cluster. (10) $V_r = -46 \pm 5$ km s^{-1} (J. G. Cohen, unpublished data). This star is not a member.

TABLE 17B

PHOTOMETRY OF M4 VARIABLES

Date JD2440000+	Observed Values					
	K	J-K	H-K	K-L	H_2O	CO
				V4		
3949	5.89	0.88	0.23	...	0.065	-0.04
3972	5.97	0.95	0.25	0.28 (3)	0.075	-0.025
3978	6.07	0.93	0.21	...	0.08	-0.02
				V13		
3949	6.34	1.05	0.22	...	0.07	0.08
3972	6.30	1.09	0.23	0.19 (3)	0.07	0.07
3978	6.36	1.05	0.20	...	0.05	0.07

TABLE 18

PHOTOMETRY OF NGC 6171 (M107)

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	
E	8.38	1.15	0.22	8.27	3.15	1.51	3.76	0.94	0.14	0.05	0.125	1
F	8.94	1.04	0.20	8.83	2.95	1.38	3.40	0.83	0.12	0.03	0.13	1
217	7.75	1.19	0.24	7.64	...	1.60	4.08	0.98	0.16	0.07	0.17	(≡V25), 2, 5
243	9.21	1.04	0.20	9.10	...	1.32	3.17	0.83	0.12	0.04	0.14	2
245	9.56	1.01	0.19	9.45	...	1.31	3.14	0.80	0.11	...	...	2
273	8.46	1.11	0.21	8.35	3.50	1.48	3.69	0.90	0.13	0.06	0.155	3
LM1	9.14	1.02	0.19	9.03	...	...	3.25	0.81	0.11	0.04	0.14	4

[a]Identifications are from Sandage and Katem 1964, except for LM 1 which is from Lloyd-Evans and Menzies 1977.
[b]$E(B-V)_0 = 0.38$ is an average of Harris and Racine 1979 and Zinn 1980. The observed H_2O and CO values were corrected by -0.02 and $+0.01$, respectively.

NOTES.—(1) Photoelectric *UBV* from Sandage and Katem 1964. (2) Photoelectric *BV* from Sandage and Katem 1974, transformed as recommended by Dickens and Roland 1972. (3) Photographic *UBV* from Dickens and Roland 1972. (4) *V* magnitude from Lloyd-Evans and Menzies 1977. (5) Noted by Lloyd-Evans and Menzies 1977 as being a variable based on one plate pair.

TABLE 19

PHOTOMETRY OF NGC 6254 (M10)

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	
H-I-15	8.80(3)	0.90(4)	0.16	8.72	...	1.24	2.78	0.75	0.11	...	0.045	A-II-50, 1
H-I-367	8.61	0.91(4)	0.14	8.53	...	1.28	2.94	0.76	0.09	...	0.08	1
H-II-161	9.02	0.91(4)	0.17	8.84	...	1.25	2.90	0.76	0.12	...	0.07	1
H-II-217	9.27	0.86(4)	0.15	9.19	...	1.20	2.76	0.71	0.10	...	0.01	1
A-I-2	7.65	1.02	0.18	7.57	...	1.54	3.29	0.87	0.13	0.03	0.065	2
A-II-24	7.94	0.96	0.17	7.86	...	1.44	3.21	0.81	0.12	0.03	0.08	2
A-III-16	8.38	0.92	0.17	8.30	...	1.36	2.93	0.77	0.12	0.01	0.02	2
A-III-21	7.90	1.01	0.18	7.82	...	1.52	3.10	0.86	0.13	0.02	0.035	2

[a]Numbers preceded by an "H" are from Harris, Racine, and de Roux 1976; those preceded by an "A" are from Arp 1955.
[b]A value of $E(B-V)_0 = 0.26$ (Harris and Racine 1979; Zinn 1980) was used. The observed H_2O and CO values were corrected by -0.01 and $+0.01$, respectively.

NOTES.—(1) Photographic *BV* values from Harris, Racine, and de Roux 1976. (2) Photographic m_{pv}, C.I. values from Arp 1955, transformed as recommended by Harris, Racine, and de Roux 1976.

xv) *NGC 5927*

The reddest nonvariables were selected from ring 2 of Menzies (1974), as well as several other particularly red stars closer to the cluster center both from his list and that of Lloyd Evans and Menzies (1977). All red variables which did not have crowding problems were observed in the infrared.

xvi) *NGC 6121*

The reddest and brightest stars from Lee (1977) were observed in the infrared, as well as a selection of fainter giants from Lee's inner ring.

xvii) *NGC 6171*

The reddest and brightest stars listed by Sandage and Katem (1964) and by Lloyd Evans and Menzies (1977) were observed in the infrared.

xviii) *NGC 6254*

The four brightest and reddest giants from Arp (1955), as well as a selection of somewhat fainter stars from Harris, Racine, and deRoux (1976), were observed in the infrared.

TABLE 20

PHOTOMETRY FOR NGC 6352

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	
17	7.00	1.13	0.25	6.93	3.15	1.47	5.22	0.99	0.20	...	0.20	4,6
18	9.18	0.98	0.20	9.11	3.93	1.65	3.66	0.84	0.15	-0.01	0.145	4,6
37	9.21	1.00	0.18	9.14	...	1.64	3.10	0.86	0.13	0.01	0.12	5
40	11.82	0.72	0.14	11.75	...	1.03	2.29	0.58	0.09	...	...	5
55	8.78(3)	1.09	0.22	8.71	...	1.65	3.55	0.95	0.17	0.03	0.115	5
111	10.95(3)	0.86	0.17	10.88	...	1.19	2.68	0.74	0.12	0.02	0.055	5
113	7.34	1.20	0.27	7.27	...	1.82	5.1	1.06	0.22	0.09	0.15	(≡V4),1,5
118	11.79(4)	0.77	0.15	11.72	...	1.12	2.52	0.63	0.10	...	...	5
142	10.78(3)	0.90	0.19	10.71	...	1.29	2.79	0.76	0.14	0.00	0.14	5
181	10.16	0.90	0.16	10.09	...	1.41	2.97	0.76	0.11	...	0.09	5
187	8.89	1.02	0.20	8.82	...	1.71	3.61	0.88	0.15	0.00	0.185	5
L36	6.98	1.17	0.34	6.91	...	...	6.2	1.03	0.29	0.46(3)	0.185	2,3

[a]Identifications are from Hartwick and Hesser 1972, except L36 which is from Lloyd-Evans and Menzies 1977. Stars 17 and 18 are from Hartwick and Hesser's Table 2, the rest from their Table 3.
[b]$E(B - V)_0 = 0.25$ (Harris and Racine 1979).

NOTES.—(1) Observed on 1979 May 11 and 1981 March 13. Measurements agreed to 0.02 mag or better; $\Delta V = 0.6$ (Lloyd-Evans and Menzies 1977). (2) A variable which Lloyd-Evans and Menzies 1977 considered a possible member although it lies quite far from cluster center; $\Delta V = 0.5$. $(V - K)_0$ if from mean V value. (3) $K - L = 0.52 \pm 0.05$; $(K - L)_0 = 0.49$. (4) Photoelectric UBV from Hartwick and Hesser 1972. (5) Photographic BV from Hartwick and Hesser 1972. (6) Radial velocity nonmember (Cohen, unpublished data).

TABLE 21

PHOTOMETRY FOR NGC 6362

Star[a]	Observed			Reddening Corrected[b]								Notes
	K	J-K	H-K	K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	
14	8.77(3)	1.01	0.17	8.74	...	1.55	3.69	0.95	0.15	...	0.17	1
17	8.76(3)	1.04	0.17	8.73	...	1.50	3.64	0.98	0.15	...	0.10	1
25	10.01	0.81(4)	...	9.98	...	1.36	3.00	0.75	...	...	...	1
32	9.99(3)	0.90	0.15	9.96	...	1.31	3.07	0.84	0.13	...	...	1
34	8.49(3)	1.05	0.19	8.46	...	1.54	3.69	0.99	0.17	...	0.14	1
36	9.04(3)	0.95	0.17	9.01	...	1.43	3.38	0.89	0.15	...	0.12	1

[a]Identifications are from Alcaino 1972.
[b]$E(B - V)_0 = 0.11$, an average of values given by Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) Photoelectric BV values from Alcaino 1972.

xix) *NGC 6352*

The five reddest giants from Hartwick and Hesser (1972), a selection of somewhat fainter stars, and one star from Lloyd Evans and Menzies (1977) were observed in the infrared.

xx) *NGC 6362*

All uncrowded stars with $B - V > 1.4$ from Alcaino (1972) were observed in the infrared.

xxi) *NGC 6397*

The brightest and reddest stars, as well as a selection of fainter giants from the lists of Woolley *et al.* (1961) and Cannon (1974), were observed in the infrared.

xxii) *NGC 6553*

Only a few of the potential giants identified in the preliminary study by Hartwick (1975) could be measured in the infrared because of severe crowding problems.

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NOTES.—(1) AGB star from V, $B - V$ diagram. (2) These stars are from Woolley *et al.* 1961. Da Costa *et al.* 1977 showed them to be likely radial velocity cluster members.

TABLE 22
NGC 6397 PHOTOMETRY

Star	Observed[a]			Reddening Corrected[b]								n	Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO		
C12	10.98(3)	0.62(3)	0.14	10.93	0.80	0.66	2.10	0.52	0.10	...	...	1	
C25	9.43	0.70(3)	0.14	9.38	1.09	0.79	2.29	0.60	0.10	...	...	1	
C28	9.13	0.68(3)	0.12	9.08	1.05	0.77	2.18	0.58	0.08	...	-0.025	1	1
C43	7.83	0.76	0.14	7.78	1.57	0.95	2.61	0.66	0.10	0.045	-0.005	1	
C132	9.98	0.68(3)	0.11	9.93	1.00	0.77	2.20	0.58	0.07	...	...	1	
C211	6.53	0.86	0.16	6.48	2.47	1.29	3.13	0.76	0.12	0.035	0.005	1	
C428	8.53	0.73(3)	0.14	8.48	1.32	0.88	2.47	0.63	0.10	...	-0.015	1	
C603	7.00	0.83	0.15	6.95	2.04	1.16	2.85	0.73	0.11	0.01	-0.02	1	
C608	10.33	0.63(3)	0.13	10.28	0.82	0.69	2.09	0.53	0.09	...	...	1	
C669	7.23	0.81	0.16	7.18	1.95	1.11	2.77	0.71	0.12	0.03	0.005	1	
RG0469	6.32	0.86	0.16	6.27		1.30	3.19	0.76	0.12	0.02	0.005	1	2
RG0698	6.70	0.82	0.15	6.65		1.29	3.09	0.72	0.11	0.03	0.01	1	2

[a]Numbers in parentheses are uncertainties in K, $J - K$, $H - K$, CO, and H_2O in units of hundredths of a magnitude when greater than 2.
[b]Photoelectric *UBV* photometry is from Cannon 1974. A value of $E(B - V)_0 = 0.18$ was adopted. Cannon 1974 and Harris and Racine 1979 both quote this value. Zinn's 1980 value of 0.16 is not significantly different.

TABLE 23

PHOTOMETRY FOR NGC 6553

Star[a]	Observed K	Observed J-K	Observed H-K	Reddening Corrected[b] K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO	Notes
I- 3	9.53(4)	1.21	0.26	9.30	...	2.15	2.80	0.77	0.10	...	0.135	1, 6
II-16	10.36(4)	1.15	0.27	10.13	...	1.60	3.37	0.72	0.11	...	...	1, 6
II-33	9.72(3)	1.12	0.25	9.49	...	2.31:	2.59	0.68	0.09	...	0.16	6
II-44	9.38(4)	1.27	0.27	9.15	...	1.84:	3.35	0.83	0.11	...	0.19	1, 6
II-54	10.10(3)	1.10	0.29	9.87	...	1.58	3.39	0.66	0.13	...	...	2, 6
II-59	7.69(3)	1.42	0.36	7.46	...	1.75:	5.11	0.98	0.20	0.04	0 24	1, 6
II-95	9.74	1.21	0.28	9.51	...	1.90	3.69	0.77	0.12	...	0.185	6
V4	6.28	1.50	0.48	6.05	...	2.02	6.45	1.06	0.32	0.46	0.20	4, 5, 6
V5	6.41	1.46	0.43	6.18	...	1.79:	7.4	1.02	0.27	0.33	0.21	3, 6

[a]Identifications are from Hartwick 1975.

[b]$E(B-V)_0 = 0.79$ is an average of values given by Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) For these stars, contamination of the reference beam required corrections to the observed K magnitudes by 0.05–0.11 mag. (2) This star is severely crowded. (3) Observed on 1981 June 26. $K - L = 0.46 \pm 0.03$; $(K - L)_0 = 0.36$. (4) Observed on 1981 June 26. $K - L = 0.51 \pm 0.03$; $(K - L)_0 = 0.41$. (5) A Mira variable with a period of 265 days (Andrews *et al.* 1974). (6) Preliminary photographic BV photometry from Hartwick 1975.

TABLE 24

M69 (NGC 6637) PHOTOMETRY

Star[a]	Observed K	Observed J-K	Observed H-K	Reddening Corrected[b] K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO	n	Notes
In-I-30	9.54	0.96	0.16	9.49	...	1.53	3.58	0.86	0.12	0.08	0.155	1	
In-II-14	9.30	1.02	0.18	9.25	...	1.54	3.87	0.92	0.14	0.05	0.14	1	
In-III-3	10.02	0.92	0.20	9.97	...	1.37	3.12	0.82	0.16	...	0.07	1	3
I-2	11.05	0.94	0.19	11.00	...	1.78	3.36	0.84	0.15	...	...	1	4
I-4	11.83	0.75	0.11	11.78	...	1.16	2.42	0.65	0.07	...	...	1	2
I-40	8.47	1.05	0.18	8.42	...	1.20	4.19	0.95	0.14	0.08	0.155	1	V3, 1
I-43	8.00	1.24	0.41	7.95	...	1.39	4.80	1.14	0.37	0.56	0.145	1	V4, 1
II-19	10.03	0.96	0.16	9.98	...	1.45	3.42	0.86	0.12	0.075	0.13	1	
II-37	8.23	1.13	0.23	8.18	...	1.64	5.55	1.03	0.19	0.13	0.20	1	V6
III-26	10.60	0.93	0.16	10.55	...	1.40	3.10	0.83	0.12	0.025	0.17	1	4
III-43	8.63	1.13	0.23	8.58	...	1.32	4.43	1.03	0.19	0.08	0.19	1	V7
P17	11.01	0.91	0.15	10.96	...	1.11	2.94	0.81	0.11	...	0.06	1	

[a]Identification numbers are from Hartwick and Sandage 1968. We have prefixed an "In" to those stars from the inner 1′ of the cluster.

[b]A value of $E(B-V)_0 = 0.17$ (Harris and Racine 1979; Zinn 1980) was used. The BV photographic photometry is from Hartwick and Sandage 1968, transformed according to the prescription of Harris 1977.

NOTES.—Data were obtained on 1978 March 29; these stars were also observed on 1976 May 19 with the following results:

	K_0	$(J-K)_0$	$(H-K)_0$	H_2O	CO
*V*3	8.38(2)	0.96(4)	0.18(3)	0.11(3)	0.12 (3)
*V*4	7.66(2)	1.16(4)	0.43(3)	0.51(2)	0.055(2)

The numbers in parentheses are the uncertainties of units of hundredths of a magnitude. *V*4 is a long-period variable. (2) Probable AGB star from location in V, $B-V$ photograph. (3) This star is misidentified as Rosino's 1962 *V*10 (Hogg's 1973 V5) in Fig. 1 of Hartwick and Sandage 1968. (4) Radial velocity nonmember (Cohen, unpublished data).

TABLE 25A

M22 (NGC 6656) PHOTOMETRY

Star[a]	Observed[b] K	J-K	H-K	Reddening Corrected[c] K_0	$(U-V)_0$	$(B-V)_0$	$(V-K)_0$	$(J-K)_0$	$(H-K)_0$	H_2O	CO	n	Notes
I-12	7.96	0.88	0.16	7.86	2.00	1.11	2.80	0.68	0.09	...	0.02	1	5
I-80	9.10	0.81	0.15	9.00	1.77	1.06	2.46	0.61	0.08	0.025	0.005	1	5
I-82	10.60	0.68	0.13	10.50	1.13	0.85	2.17	0.48	0.06	...	0.005	1	5, 9
I-92	7.66	0.91	0.17	7.56	2.19	1.16	2.95	0.71	0.10	...	0.04	1	5
II-26	7.20	0.97	0.19	7.10	...	1.32	3.22	0.77	0.12	0.045	0.03	1	7
II-31	8.12	0.87	0.17	8.02	2.05	1.16	2.88	0.67	0.10	0.04	0.045	1	5
III-3	6.82	1.02	0.19	6.72	3.03	1.50	3.19	0.82	0.12	0.045	0.13	1	5
III-12	7.43	0.98	0.17	7.33	2.59	1.31	3.13	0.78	0.10	0.055	0.09	2	5
III-14	6.78	1.00	0.18	6.68	2.82	1.47	3.38	0.80	0.11	0.05	0.05	1	5
III-52	7.44	0.96	0.18	7.34	2.76	1.34	3.12	0.76	0.11	0.055	0.11	2	5
III-75	10.36(3)	0.61(3)	0.14(3)	10.26	1.04	0.83	1.74	0.41	0.07	...	0.04	1	5
III-106	8.68(3)	0.80	0.15	8.58	...	1.17	2.51	0.60	0.08	0.05	0.09	1	8
IV-20	8.17	0.89	0.14	8.07	...	1.17	2.96	0.69	0.07	0.04	0.04	1	6
IV-97	6.79	0.98	0.19	6.69	2.89	1.47	3.21	0.78	0.12	0.105	0.04	1	3, 5, V30
IV-99	9.93	0.73	0.14	9.83	...	0.85	2.46	0.53	0.07	...	0.045	1	6
IV-102	6.81	0.98	0.19	6.71	2.95	1.48	3.34	0.78	0.12	0.06	0.045	1	4, 5
V5	6.73	0.91	0.19	6.63	2.75	1.40	3.2	0.71	0.12	0.06	0.025	4	1,2
V8	6.93	0.84	0.20	6.83	2.47	1.30	2.9	0.64	0.13	0.145	0.025	3	1,2
V9	6.75	0.98	0.19	6.65	3.32	1.60	3.5	0.78	0.12	0.045	0.10	4	1, 2

[a]Identification numbers are from Arp and Melbourne 1959.

[b]Numbers in parentheses are uncertainties in K, $J - K$, $H - K$, H_2O, and CO in units of hundredths of a magnitude when greater than 2.

[c]An $E(B - V)_0 = 0.36$ was used. This is an average of the values given by Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) Infrared values are means from Table 25B; *UBV* values are means from Eggen 1977. (2) Reddening corrected $(K - L)_0$ values for *V*5, *V*8, and *V*9, are 0.14 ± 0.03, 0.24 ± 0.03, and 0.14 ± 0.04, respectively. (3) $(K - L)_0 = 0.08 \pm 0.03$. (4) $(K - L)_0 = 0.11 \pm 0.03$. (5) *UBV* photoelectric photometry from Eggen 1977. (6) Photographic *BV* photometry from Lloyd-Evans 1975. (7) Because of potential problems with the photoelectric photometry for this star (Lloyd Evans 1978), we have used the photographic values from Lloyd Evans 1975. (8) Photoelectric values from Hartwick, Hesser, and McClure 1977. (9) Radial velocity nonmembers (Cohen, unpublished data).

TABLE 25B

PHOTOMETRY OF THE M22 VARIABLES

Date JD2440000+	Observed Values K	J-K	H-K	K-L	H_2O	CO
			V5			
3701	6.76	0.94	0.19	...	0.06	0.005
3773	6.70	0.90	0.20	0.18 (3)	0.09	0.01
3774	6.72	0.91	0.19	...	0.08	0.01
3977	6.75	0.89	0.16	...	0.065	0.03
4006	6.75 (3)	0.90 (3)	0.19 (3)	...	0.07 (5)	0.05
4149	6.70 (3)	0.91	0.19	0.16 (3)	0.07	-0.005
			V8			
3701	6.85	0.86	0.22	...	0.075	-0.035
3774	6.98	0.85	0.21	0.28 (3)	0.18	0.00
3977	6.97	0.80	0.18	...	0.22	0.08
4149	6.92 (3)	0.83	0.22	0.33 (3)	0.245	0.03
			V9			
3701	6.75	1.00	0.19	...	0.05	0.08
3772	6.71	0.99	0.20	0.18 (4)	0.085	0.08
3774	6.72	0.98	0.19	...	0.075	0.08
3977	6.81	0.97	0.17	...	0.025	0.125
4006	6.75 (3)	0.99 (3)	0.21 (3)	...	0.07 (5)	0.08

TABLE 26

NGC 6752 PHOTOMETRY

Star	Observed			Reddening Corrected[a]								n	Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO		
C1	9.91	0.62	0.13	9.90	1.30	0.85	2.40	0.61	0.12	...	...	1	3
C3	8.42	0.79	0.13	8.41	2.28	1.22	3.00	0.78	0.12	...	0.04	1	
C9	9.67	0.69	0.10	9.66	1.68	1.00	2.62	0.68	0.09	...	...	1	
C48	10.31	0.56	0.08	10.30	1.12	0.80	2.23	0.55	0.07	...	...	1	3
C112	10.45	0.60	0.11	10.44	1.02	0.75	2.17	0.59	0.10	...	...	1	3
C118	9.42	0.73	0.11	9.41	1.82	1.04	2.68	0.72	0.10	...	...	1	
C119	10.50	0.64	0.09	10.49	1.39	0.90	2.42	0.63	0.08	...	...	1	
C121	11.00	0.66	0.14	10.99	1.25	0.82	2.39	0.65	0.13	...	...	1	
C122	10.14	0.64	0.11	10.13	1.48	0.97	2.51	0.63	0.10	...	...	1	
C124	10.81	0.63	0.12	10.80	1.23	0.83	2.33	0.62	0.11	...	...	1	
C126	8.14	0.79	0.14	8.13	2.38	1.27	3.08	0.78	0.13	...	0.05	1	1
C135	8.54	0.72	0.12	8.53	1.96	1.12	2.82	0.71	0.11	...	0.015	1	3
A9	8.29	0.76	0.13	8.28	2.03	1.17	2.93	0.75	0.12	...	0.035	1	3
A12	7.94	0.85	0.14	7.93	2.56	1.32	3.23	0.84	0.13	0.04	0.065	1	
A16	6.79	1.05	0.23	6.78	3.29	1.53	4.66	1.04	0.22	0.065	0.20	2	2
A29	8.93	0.78	0.14	8.92	1.98	1.11	2.84	0.77	0.13	...	0.035	1	
A31	7.03	0.96	0.16	7.02	3.21	1.57	3.69	0.95	0.15	0.05	0.05	1	
A45	8.49	0.80	0.14	8.48	2.28	1.20	3.00	0.79	0.13	...	0.03	1	
A59	7.18	0.93	0.16	7.17	3.32	1.56	3.64	0.92	0.15	0.06	0.07	1	
A61	8.72	0.73	0.13	8.71	2.05	1.10	2.91	0.72	0.12	...	0.05	1	

[a]Photoelectric *UBV* photometry from Cannon and Stobie 1973. Numbers preceded by a "C" are identified in Cannon and Stobie; those preceded by an "A" are identified in Alcaino 1970.

Cannon 1974 gives $E(B-V) = 0.04$; Harris and Racine 1979 give 0.03; Zinn 1980 gives 0.00, which seems rather low in view of the galactic latitude of the cluster (−25°6). We have adopted $E(B-V) = 0.03$.

NOTES.—(1) Cannon and Stobie suggest that this is a small-amplitude red variable. (2) Cannon and Stobie quote R. J. Dickens as to this star having TiO band and being a radial velocity cluster member. Eggen 1972, though, claims it is a field star on the basis of *R*, *I* photometry. The red colors and strong CO support this conclusion. (3) Probable AGB star from *V*, $B-V$ diagram.

TABLE 27

M15 (NGC 7078) PHOTOMETRY

Star[a]	Observed			Reddening Corrected[b]								n	Notes
	K	J-K	H-K	K_o	$(U-V)_o$	$(B-V)_o$	$(V-K)_o$	$(J-K)_o$	$(H-K)_o$	H_2O	CO		
I-12	9.42	0.77	0.13	9.39	...	1.24	2.95	0.72	0.11	0:05	0.01	2	1
II-29	10.30	0.73	0.13	10.27	...	1.08	2.49	0.68	0.11	-0.01	0.00	1	1, 3
II-64	10.57	0.69	0.14	10.54	...	0.99	2.54	0.64	0.12	0.04	0.00	1	1
II-75	9.92	0.73	0.11	9.89	1.86	1.14	2.80	0.68	0.09	0.06	0.00	2	2
S6	10.40	0.70	0.12	10.37	1.85	1.09	2.72	0.65	0.10	0.06	0.02	1	2

[a]Identifications are from Arp 1955.

[b]$E(B - V) = 0.10$ was used. This is an average of Harris and Racine 1979 and Zinn 1980.

NOTES.—(1) Photographic potometry from Arp 1955. (2) Photoelectric photometry from Sandage 1970. (3) AGB star on basis of location in V, $B - V$ plot.

TABLE 28

PHYSICAL PARAMETERS FOR CLUSTER STARS

Star	BC_K	M_{bol}	T_e	log g	Notes
		NGC 288			
C19	1.96	-0.33	4820	2.0	
C20	2.40	-2.50	4134	0.8	
C23	1.96	-0.12	4840	2.1	
C32	1.91	0.39	4910	2.3	
C33	2.14	-1.19	4464	1.5	
C36	2.16	-1.37	4442	1.4	
A77	2.32	-2.31	4254	1.0	
A78	2.39	-2.61	4161	0.8	
A80	2.11	-1.31	4526	1.5	
A96	2.44	-2.89	4084	0.7	
A194	2.29	-2.29	4300	1.0	
A231	2.16	-1.67	4477	1.3	
A245	2.21	-1.91	4396	1.2	
A260	2.64	-3.53	3821	0.3	V1, SR
		NGC 362			
I-2	2.09	-1.11	4608	1.6	
I-23	2.26	-2.10	4335	1.1	
I-44	2.27	-2.43	4337	1.0	
I-52	2.01	-0.37	4640	1.9	AGB
II-20	2.46	-3.02	3994	0.6	
II-40	1.99	-0.44	4770	1.9	
II-43	2.04	-1.59	4667	1.4	AGB
II-47	1.96	-1.08	4790	1.7	AGB
II-49	2.15	-1.50	4445	1.4	
III-4	2.25	-1.87	4320	1.2	
III-11	2.56	-3.51	3910	0.3	
III-25	2.20	-1.97	4399	1.2	
III-37	2.25	-2.43	4356	1.0	
III-39	2.45	-3.28	4048	0.5	
III-44	2.45	-3.00	4063	0.6	
III-63	2.52	-3.25	3943	0.5	
III-70	2.35	-2.91	4202	0.7	
IV-84	2.42	-2.80	4074	0.7	
IV-91	2.18	-2.05	4419	1.1	f
IV-100	2.54	-3.25	3916	0.5	
V2	2.62	-3.52	3848	0.3	SR
		NGC 1261			
3	2.51	-3.01	3955	0.6	
9	2.54	-3.42	3960	0.4	
10	2.50	-3.10	3961	0.5	
11	2.38	-2.32	4157	0.9	
52	2.35	-2.72	4210	0.8	
81	2.32	-2.83	4284	0.8	
IR-1	2.65	-3.27	3850		
		NGC 1851			
3	2.40	-2.75	4134	0.7	
95	2.46	-2.87	4038	0.7	
112	2.45	-2.61	4054	0.8	
151	2.35	-2.59	4188	0.8	
168	2.59	-3.53	3865	0.3	V24
262	2.49	-3.20	3968	0.5	
279	2.32	-2.33	4227	1.0	
294	2.53	-3.20	3931	0.5	
333	2.33	-2.25	4213	1.0	
IR-1	2.67	-3.66	3800		
IR-4	2.63	-3.71	3900		
IR-11	2.5	-3.7	3950		doub.
		NGC 1904 (M79)			
35	2.39	-3.38	4194	0.5	
41	2.29	-3.31	4334	0.6	V2, SR
50	2.29	-2.75	4323	0.8	
51	2.32	-2.97	4270	0.7	
53	2.45	-3.52	4060	0.4	
81	2.34	-3.08	4250	0.7	
IR-1	2.36	-3.37	4200		
IR-5	2.36	-3.23	4200		
IR-7	2.44	-3.29	4050		
IR-8	2.42	-3.30	4100		
		NGC 2298			
7	2.25	-2.76	4351	0.8	
8	2.25	-2.78	4358	0.8	
9	2.24	-2.25	4348	1.0	
11	2.07	-2.30	4624	1.1	
31	2.17	-2.29	4466	1.1	
IR-1	2.36	-3.00	4200		
		NGC 2808			
11	2.51	-3.17	3961	0.5	
13	2.19	-2.86	4518	0.9	
14	2.46	-3.41	4089	0.5	
15	2.64	-3.55	3850	0.3	
19	2.43	-3.42	4138	0.5	
20	2.35	-3.32	4247	0.6	
22	2.44	-2.86	4072	0.7	
39	2.35	-2.80	4200	0.8	
65	2.49	-3.45	3994	0.4	
82	2.11	-2.95	4640	0.9	
87	2.40	-3.05	4190	0.6	
204	2.45	-2.78	4070	0.7	
		NGC 4372			
1	2.38	-3.42	4131	0.5	mem?
2	2.34	-3.29	4195	0.6	
2002	2.20	-2.87	4414	0.8	
2017	2.46	-3.94	3966	0.2	f
2063	2.24	-3.18	4339	0.7	
2121	2.24	-2.61	4332	0.9	
3010	2.12	-2.70	4582	0.9	
3033	2.29	-3.05	4251	0.7	
3035	2.00	-2.57	4759	1.1	f
4002	2.69	-4.27	3702	-0.1	f
		NGC 4590			
A-14	2.31	-3.09	4279	0.7	
I-82	2.30	-3.12	4287	0.7	
I-144	2.25	-2.82	4372	0.8	
I-256	2.21	-2.93	4438	0.8	
I-260	2.27	-3.16	4329	0.7	
G	2.61	-4.07	3797	0.1	f
ZNG2	2.16	-3.06	4501	0.8	
		NGC 4833			
MA1	2.29	-3.15	4273	0.6	
MA18	2.35	-3.22	4184	0.6	f
MA75	2.42	-3.18	4056	0.5	
MA100	2.87	-4.30	3519	-0.2	f
B55	2.37	-3.19	4169	0.6	
B172	2.25	-2.92	4323	0.8	
C81	2.28	-2.81	4296	0.8	
D75	2.33	-3.13	4224	0.6	
V16	2.30	-2.98	4244	0.7	
V9	2.26	-3.34	4321	0.6	
		NGC 5024 (M53)			
G	2.32	-2.98	4241	0.7	
K	2.40	-3.42	4139	0.5	V50
1-2-8	2.28	-2.99	4296	0.7	
1-2-18	2.34	-3.19	4224	0.6	
4-4-16	2.29	-2.96	4282	0.7	V49
1-6-5	2.35	-3.19	4212	0.6	
3-6-4	2.36	-3.31	4184	0.5	
IR-1	2.21	-3.43	4400		
		NGC 5286			
4	2.35	-2.76	4187	0.8	
49	2.30	-2.74	4251	0.8	
50	2.26	-2.78	4326	0.8	
97	2.34	-3.19	4228	0.6	
101	2.25	-2.71	4363	0.9	
107	2.34	-2.95	4209	0.7	f?
		NGC 5897			
9	2.38	-3.10	4177	0.6	
160	2.30	-2.89	4298	0.8	
209	2.33	-2.67	4220	0.8	
255	2.49	-3.29	3958	0.5	
263	2.47	-3.36	3996	0.4	
V5	2.43	-3.27	4093	0.5	Irr.
		NGC 5904 (M5)			
I-1	1.81	-0.53	5027	2.0	AGB
I-4	2.20	-1.67	4387	1.3	
I-14	2.29	-2.19	4261	1.0	
I-20	2.33	-2.71	4241	0.8	
I-25	2.16	-1.43	4436	1.4	
I-55	1.99	-1.24	4751	1.6	AGB
I-61	2.19	-1.73	4382	1.3	
I-67	1.82	-0.79	4993	1.9	AGB
I-68	2.40	-2.96	4128	0.7	
II-9	2.30	-2.83	4303	0.8	
II-50	2.16	-1.07	4407	1.5	
II-51	2.05	-0.94	4619	1.7	
III-3	2.41	-2.99	4118	0.6	
III-16	1.84	-0.59	4958	1.9	AGB
III-36	2.31	-2.43	4254	0.9	
III-53	2.00	-1.37	4718	1.5	AGB
III-56	2.06	-1.62	4623	1.4	AGB
III-78	2.36	-2.70	4182	0.8	
IV-3	1.90	0.19	4890	2.2	
IV-19	2.37	-2.72	4159	0.8	
IV-28	2.06	-0.51	4632	1.8	
IV-47	2.42	-3.01	4107	0.6	
IV-59	2.26	-2.51	4318	0.9	
IV-81	2.48	-3.33	3987	0.4	
IV-86	1.49	0.32	5460	2.5	AGB
		NGC 5927			
23	2.29	-1.25	4249	1.4	
100	2.84	-3.82	3552	0.1	
157	2.33	-1.03	4151	1.4	
532	2.59	-2.50	3856	0.7	
536	2.38	-1.50	4082	1.2	
563	2.18	-0.53	4381	1.7	
587	2.15	-0.57	4411	1.7	
622	2.46	-2.05	3983	1.0	
627	2.76	-2.89	3638	0.5	
799	2.80	-3.11	3606	0.4	
857	2.27	-0.85	4256	1.6	
LM9	2.82	-3.22	3562	0.3	
LM21	2.79	-3.27	3591	0.3	
V3	2.96	-4.52	3210	-0.4	LPV
V5	2.88	-3.40	3510	0.2	
V6	2.85	-3.16	3526	0.3	
V8	2.90	-3.36	3445	0.2	
V9	2.93	-3.41	3383	0.1	

TABLE 28—*Continued*

Star	BC_K	M_{bol}	T_e	log g	Notes
		NGC 6121 (M4)			
2206	2.32	-1.58	4172	1.2	
3209	2.46	-2.74	4025	0.7	
2307	2.51	-2.20	3950	0.9	
3303	2.40	-1.76	4056	1.1	f
1403	2.30	-1.33	4214	1.3	
1411	2.55	-2.76	3915	0.6	
1412	2.36	-3.45	4122	0.5	V4
2406	2.50	-2.86	3935	0.6	V13
3413	2.34	-2.17	4159	1.0	
1514	2.64	-3.26	3796	0.4	
1605	2.25	-0.95	4268	1.5	
1608	2.07	0.02	4624	2.0	
1621	2.00	0.38	4740	2.2	
1622	2.05	0.23	4649	2.1	
2608	2.25	-1.09	4286	1.5	
2617	2.42	-1.71	4043	1.1	
2623	2.10	-0.25	4482	1.9	
2626	2.23	-0.88	4296	1.6	
3612	2.34	-1.57	4150	1.2	
3624	2.37	-1.73	4118	1.1	
4611	2.72	-3.26	3724	0.4	
4613	2.67	-3.31	3786	0.4	
4624	2.09	-0.50	4482	1.8	
4630	2.29	-1.20	4206	1.4	
4633	2.24	-1.48	4286	1.3	
3713	2.60	-2.74	3859	0.6	
		NGC 6171 (M107)			
E	2.57	-2.87	3885	0.6	
F	2.44	-2.44	4019	0.8	
217	2.65	-3.42	3785	0.3	V25
243	2.37	-2.24	4144	1.0	
245	2.35	-1.91	4168	1.1	
273	2.54	-2.82	3907	0.6	
LM1	2.40	-2.28	4099	0.9	
		NGC 6254 (M10)			
H-I-15	2.21	-2.29	4405	1.0	
H-I-367	2.27	-2.42	4295	0.9	
H-II-161	2.26	-2.12	4314	1.1	
H-II-217	2.19	-1.84	4410	1.2	
A-1-2	2.43	-3.22	4110	0.5	
A-II-24	2.38	-2.98	4149	0.7	
A-III-16	2.28	-2.64	4317	0.9	
A-III-21	2.37	-3.03	4221	0.7	
		NGC 6352			
17	2.84	-3.78	3538	0.1	f
18	2.52	-1.92	3917	1.0	f
37	2.37	-2.04	4181	1.0	
40	1.95	0.15	4840	2.2	
55	2.53	-2.31	3948	0.8	
111	2.17	-0.50	4415	1.8	
113	2.86	-3.42	3553	0.2	V4
118	2.07	0.24	4624	2.1	
142	2.23	-0.61	4327	1.7	
181	2.29	-1.17	4234	1.4	
181	2.52	-2.21	3928	0.9	
L36	2.91	-3.73	3382	0.0	var., f?
		NGC 6362			
14	2.56	-2.95	3906	0.6	
17	2.55	-2.97	3925	0.6	
25	2.29	-1.98	4240	1.1	
32	2.34	-1.95	4210	1.1	
34	2.57	-3.22	3908	0.5	
36	2.46	-2.78	4039	0.7	
		NGC 6397			
C12	1.81	1.02	5000	2.6	
C25	1.94	-0.40	4840	2.0	
C28	1.88	-0.76	4947	1.9	AGB
C43	2.10	-1.84	4526	1.3	
C132	1.88	0.09	4930	2.2	
C211	2.34	-2.90	4203	0.7	
C428	2.03	-1.21	4669	1.6	
C603	2.23	-2.54	4374	0.9	
C608	1.81	0.37	5009	2.3	
C669	2.19	-2.35	4421	1.0	
RG0469	2.36	-3.09	4173	0.6	
RG0698	2.31	-2.76	4221	0.8	
		NGC 6553			
I-3	2.26	-2.06	4370	1.1	
II-16	2.40	-1.09	4012	1.4	
II-33	2.17	-1.96	4520	1.2	
II-44	2.44	-2.03	4028	1.0	
II-54	2.39	-1.36	4008	1.2	
II-59	2.83	-3.33	3551	0.3	
II-95	2.51	-1.60	3905	1.1	
V4	2.95	-4.62	3336	-0.4	LPV
V5	2.98	-4.46	3106	-0.4	LPV?
		NGC 6637 (M69)			
In-I-30	2.50	-2.87	3937	0.6	
In-II-14	2.59	-3.02	3850	0.5	
In-III-3	2.36	-2.53	4190	0.9	
I-2	2.45	-1.41	4027	1.2	f
I-4	2.04	-1.04	4712	1.7	AGB?
I-40	2.66	-3.78	3753	0.2	V3
I-43	2.86	-4.05	3600	0.0	V4, LPV
II-19	2.46	-2.42	3997	0.8	
II-37	2.88	-3.80	3484	0.0	V6
III-26	2.35	-1.96	4173	1.1	f
III-43	2.74	-3.54	3683	0.2	V7
P17	2.28	-1.62	4272	1.3	
		NGC 6656 (M22)			
I-12	2.19	-2.40	4397	1.0	
I-80	2.04	-1.41	4675	1.5	
I-82	1.86	-0.09	4950	2.1	f
I-92	2.26	-2.63	4300	0.9	AGB?
II-26	2.37	-2.98	4149	0.7	AGB?
II-31	2.22	-2.21	4333	1.0	
III-3	2.38	-3.35	4165	0.5	
III-12	2.34	-2.78	4189	0.8	
III-14	2.43	-3.34	4062	0.5	
III-52	2.34	-2.77	4192	0.8	
III-75	1.63	-0.56	5352	2.1	AGB
III-106	2.06	-1.81	4617	1.3	
IV-20	2.25	-2.13	4278	1.1	
IV-97	2.38	-3.38	4165	0.5	V30
IV-99	2.00	-0.62	4667	1.8	
IV-102	2.42	-3.32	4086	0.5	
V5	2.35	-3.47	4175	0.5	
V8	2.23	-3.39	4361	0.6	Irr.
V9	2.46	-3.34	3964	0.4	
		NGC 6752			
C1	2.00	-1.20	4730	1.6	AGB
C3	2.30	-2.39	4259	0.9	
C9	2.12	-1.32	4498	1.5	
C48	1.90	-0.90	4900	1.8	AGB
C112	1.87	-0.79	4951	1.8	AGB
C118	2.16	-1.53	4461	1.4	
C119	2.01	-0.59	4712	1.8	
C121	2.00	-0.11	4740	2.0	
C122	2.06	-0.91	4632	1.7	
C124	1.97	-0.33	4800	2.0	
C126	2.33	-2.64	4219	0.8	var.?
C135	2.21	-2.36	4383	1.0	AGB
A9	2.26	-2.56	4312	0.9	AGB
A12	2.39	-2.78	4133	0.7	
A16	2.78	-3.54	3625	0.2	f
A29	2.24	-1.94	4353	1.2	
A31	2.56	-3.52	3915	0.3	
A45	2.30	-2.32	4258	1.0	
A59	2.54	-3.39	3926	0.4	
A61	2.24	-2.15	4310	1.1	
		NGC 7078 (M15)			
I-12	2.27	-3.29	4325	0.6	
II-29	2.07	-2.61	4649	1.0	AGB
II-64	2.08	-2.33	4608	1.1	
II-75	2.19	-2.87	4416	0.8	
S6	2.15	-2.43	4460	1.0	

NOTE.—Log *g* is calculated with the assumption that all stellar masses = 0.8 $M_{\odot}$. The reddening corrected distance moduli used are NGC 288-14.64; NGC 362-14.78; NGC 1261-15.79; NGC 1851-15.44; NGC 1904-15.60; NGC 2298-15.18; NGC 2808-14.90; NGC 4372-13.46; NGC 4590-14.94; NGC 4833-13.70; NGC 5024-16.24; NGC 5286-14.80; NGC 5897-15.46; NGC 5904-14.42; NGC 5927-14.43; NGC 6121-11.60; NGC 6171-13.71; NGC 6254-13.22; NGC 6352-13.55; NGC 6362-14.25; NGC 6397-11.72; NGC 6553-13.62; NGC 6637-14.86; NGC 6656-12.45; NGC 6752-13.10; NGC 7078-14.95.

xxiii) *NGC 6637*

Crowding problems limited the number of giants from the list of Hartwick and Sandage (1968) which could be observed in the infrared.

xxiv) *NGC 6656*

The reddest and brightest giants from Arp and Melbourne's (1959) list were observed in the infrared, as well as a selection of fainter giants.

xxv) *NGC 6752*

Nearly all of the giants with $B-V>1.1$ from the lists of Cannon and Stobie (1973) and Alcaino (1970) were observed in the infrared. A selection of bluer giants was also observed.

xxvi) *NGC 7078*

Only a few of the red giants from Arp's (1955) list were measured in the IR.

b) Completeness

A major issue in the companion paper, GC9, concerns the luminosities of the brightest stars in the clusters. Thus, it is important to ascertain whether we have in fact observed the brightest red giants—particularly the three brightest ones. Aside from observational uncertainties, there is a good correlation between a star's V and K magnitudes, and the K magnitudes, in turn, are closely tied to the bolometric luminosities. Many of the clusters in our program have optical photometry available right into the cluster center, and for these it is probable that the three brightest stars have been measured. A number of those lacking complete photometry were scanned at K with one of the telescopes used for the photometry. Stars found in the course of scanning which had luminosities and colors comparable to those of the visually brightest red stars were noted, and infrared photometry was subsequently obtained for most of them. Table 29 summarizes the situation for the 26 newly observed clusters and for the clusters for which we have already published data (M3, M13, and M92 in GC1; M71 and 47 Tuc in GC2 and GC5; ω Cen in GC3; NGC 3201 in Da Costa, Frogel, and Cohen 1981, hereafter GC6; and NGC 7006 in Cohen and Frogel 1982, hereafter GC7). Only Pal 12 (Cohen *et al.* 1980) has been excluded because of its extreme sparseness. Perhaps the most surprising result from the scans is that even in quite rich clusters, optical photometry of the outer regions had, with only very few exceptions, already uncovered stars at or close to the maximum brightness of any subsequently found to exist in the cluster. Thus, it seems likely that even in clusters with incomplete photometry and which have not been scanned (which comprise one-third of the 33 clusters), our samples of bright stars are nearly complete.

TABLE 29

EXTENT OF STELLAR SURVEYS IN THE GLOBULAR CLUSTERS

NGC	Notes	Metallicity Group
104	1	A
288	1	C2
362	3	B
1261	2	B
1851	2	B
1904	2	C2
2298	2	D
2808	2	B
3201	1	C1
4372	1	C2
4590	2	D
4833	1	D
5024	2	D
5272	6	C2
5286	3	C2
5897	1	C1
5904	6,7	C1
5927	3	A
6121	1	C1
6171	1	B
6205	3,7	C2
6254	6,7	C2
6341	3	D
6352	1	A
6362	1	B
6397	4	D
6553	5	A
6637	4	A
6656	2	D
6752	3	C1
6838	1	A
7006	3	C1
7078	3	D

(1) NOTES.—(1) Optical stellar photometry is available in the cluster center. The brightest and reddest stars were measured in the infrared. (2) Central region of cluster was scanned in the infrared, and all bright, red, sources were measured. If they are comparable to the brightest stars with optical photometry, the data are included in the tables of this paper. (3) The cluster center is rich in stars. No optical photometry is available for stars in the center, nor was the cluster scanned in the infrared. (4) Cluster center is rather poor in stars, but no optical photometry is available for the central region, nor was the cluster scanned in the infrared. (5) A limited amount of optical and infrared photometry is available in the cluster center. There are severe crowding and field star contamination problems. (6) Cluster was scanned in the infrared. One to three sources were found which are close (0.1 to 0.3 mag) to the brightest star selected optically; these sources were not subsequently photometered in the infrared, however. (7) The *C-M* diagrams of Arp 1955 show one or two red variables at or near the top of the GB. These stars were not measured in the infrared.

c) Field Star Contamination

A number of the stars observed are field stars, as indicated both in the notes to Table 2–27 and by an "f" in the "Notes" column of Table 28. Field stars were picked out from radial velocity information such as the compilation of Webbink (1981), the study of M22 by Lloyd Evans (1978), or from our own unpublished radial velocities. A few stars have anomalously strong CO indices for their colors and the metallicity of the cluster. These are almost certainly field giants and are so indicated in the data tables.

IV. BROAD-BAND COLORS AND H_2O ABSORPTION

We have divided the clusters into five metallicity groups to facilitate dealing with the large number of data. The most metal-rich clusters, with $[Fe/H]_Z$ (the metallicity on the Zinn 1980 scale) greater than -0.7, are in group A. Group B includes clusters with $-1.4 < [Fe/H]_Z < -0.7$, while group C includes those with $-1.8 < [Fe/H]_Z \leq -1.4$, and group D includes those more metal poor than $[Fe/H]_Z = -1.8$. To keep the groups of approximately equal size, group C was further subdivided, with group C1 covering the range $-1.6 \leq [Fe/H]_Z \leq -1.4$ and group C2 covering the remainder of the interval. The group memberships are given in Table 29. We now examine the color-color relationships and H_2O absorption using the data of Tables 2–27.

a) $(U-V)_0$, $(V-K)_0$ *Colors*

The behavior of the relationship between $(U-V)_0$ and $(V-K)_0$ for globular cluster giants as deduced from our initial observations (GC1; GC2) is fully confirmed by the complete cluster sample. In the mean, nearly all stars from the metal-poor clusters, groups B, C, and D, lie close to the line defined by M3, M13, and M92. Those clusters not in group A but with high quality *UBV* photoelectric data, e.g., M3, M13, M92 (GC1), NGC 3201 (GC6), NGC 6397, and NGC 6752, have little internal star-to-star scatter and are virtually indistinguishable from one another. M4 seems to be the one notable exception, and its stars' location shown in Figure 1*a* is taken as evidence that its $E(B-V)$ is underestimated by ~ 0.1 mag, as discussed in the Appendix to GC9 and in § VI*e* here. Systematic deviation from the metal-poor line sets in for clusters close to $[Fe/H]_Z = -1.0$; all stars in group A clusters lie between this line and the field line.

The group A stars whose $(U-V)_0$, $(V-K)_0$ colors are displayed in Figure 1*b* show more scatter in their $(U-V)_0$, $(V-K)_0$ relationship. The origin of this scatter is not known, although variable reddening can probably be ruled out since 47 Tuc, with an $E(B-V)$ of only 0.04, shows it as well. We can also rule out the effects of blanketing by CN since the strong and weak CN stars in 47 Tuc (GC5; Norris and Freeman 1979) and M71 (GC2; Smith and Norris 1982) cannot be distinguished from one another. A reasonable guess as to the cause of the scatter would be that it is related to other molecular abundance variations.

Finally, we point out the good agreement between the colors of the metal-rich cluster stars and field giants for $(V-K)_0$ between 3.5 and 5.5. This agreement adds to our confidence in the application of the $V-K$, $T_{\rm eff}$ scale, derived from observations of field stars in this color range, to the cluster stars as discussed in § V.

b) H_2O *Absorption and its Effect on JHK Colors*

The dependence of the H_2O index on $(V-K)_0$ for stars in the most metal-rich clusters of group A is shown in Figure 2. For the metal-poor groups B, C, and D, hardly any stars depart from the mean line for field giants (Aaronson, Frogel, and Persson 1978) which is essentially the locus for no H_2O absorption for $(V-K)_0 < 3.5$ as discussed in GC1. Of those stars with excess H_2O, almost all are variables—even in the most metal-poor clusters—and a number of these are not especially cool as judged by their $(V-K)_0$ colors (e.g., V8 and V30 in M22). Star 15 in NGC 2808 is rather unusual. It has strong H_2O and red $H-K$, is not an M dwarf (because of its *JHK* colors), and is the brightest star in the cluster.

H_2O absorption can strongly modify the *JHK* colors of giants (see GC5). Figure 3 shows the $(J-H)_0$, $(H-K)_0$ colors of stars in the group A clusters. There is a marked sequence of stars leading down and to the right from the mean field line. As we did for 47 Tuc (Fig. 8 of GC5), we measure the displacement in magnitudes from the mean field line in Figure 3, and its equivalent for groups B–D, along a line of slope 45°. This quantity is defined as ΔJHK. ΔH_2O measures the excess H_2O absorption and is defined as the distance above the field line in Figure 2 at the appropriate $(V-K)_0$. Plotted in Figure 4 is ΔJHK versus ΔH_2O for all of the variables and other stars that depart significantly from the mean relations in Figures 2 and 3 (and their equivalents for metallicity groups B–D) and a number of the variables from 47 Tuc. The statistics have been considerably improved as compared to Figure 8 of GC5, but the conclusion remains the same: H_2O absorption can strongly affect the *JHK* colors of the reddest stars.

We can separate the effects of the H_2O absorption upon each of the three broad-band filters as follows. If absorption by H_2O is confined only to the *H* bandpass, then ΔJHK is a measure of the absorption at *H*, and stars move from the regime of the mean field line along a locus with a slope of $-45°$. However, we showed in GC5 that H_2O absorption affects the broad-band *K* magnitude in the proportion $\Delta K \approx 0.2 \times (H_2O \text{ index})$.[3]

[3] This was established by comparing the broad-band *K* magnitudes ($\Delta\lambda = 0.4$ μm) with the narrow-band 2.20 μm continuum magnitudes ($\Delta\lambda = 0.1$ μm); the latter filter is that used to form the CO and H_2O indices. Because of H_2O and CO absorption, the difference between these two magnitudes is a *lower limit* to the effect upon the *K* magnitude, and correlates with the H_2O index itself as given above.

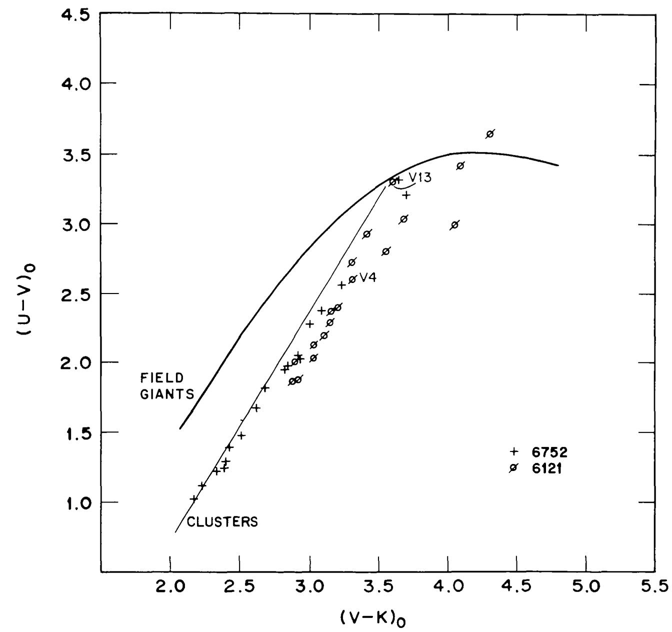


FIG. 1*a*

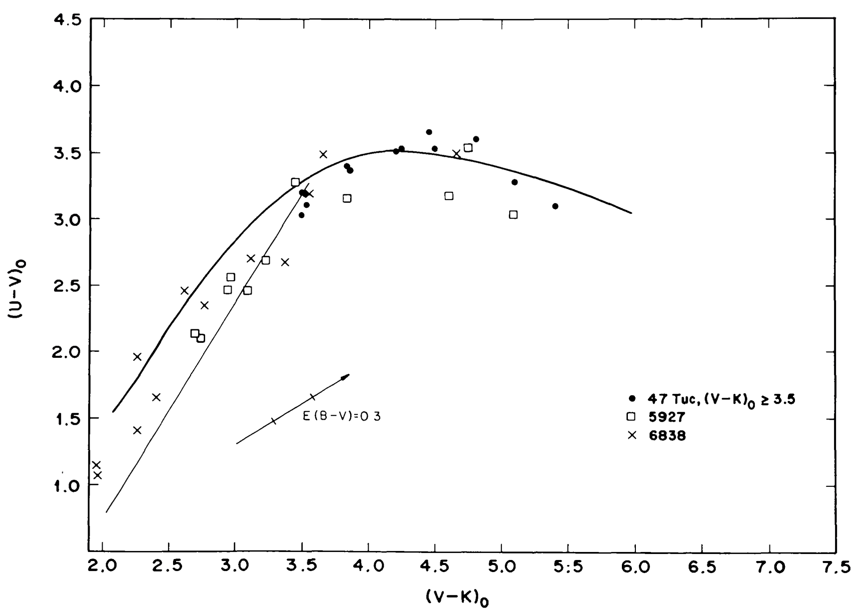


FIG. 1*b*

FIG. 1.—(*a*) $(U-V)_0$, $(V-K)_0$ data for individual stars are plotted for each of the metallicity group C1 clusters. Curved line is the mean relation for field giants as given by Johnson (1966) and Lee (1970). Straight line segment is that for the metal-poor clusters M3, M13, and M92 (GC1). NGC 3201 stars have not been plotted, but, as may be seen from Fig. 3 of GC6, they would all lie close to the metal-poor line. (*b*) Same as (*a*) for the metal-rich clusters of group A.

For example, the star NGC 5927-V3, has $\Delta JHK \approx 0.2$ (see Fig. 3) and has $\Delta H_2O \approx 0.5$ (see Fig. 2). The observed H_2O index for this star is 0.65; thus, the K magnitude has been made fainter, and $H-K$ bluer, by 0.2×0.65 mag $= 0.13$ mag, due solely to H_2O absorption within the K filter bandpass.

The locus of stellar data points leading away from the unaffected stars actually has a slope of about -0.65. Because these stars lie on a sequence, and because the locations in this plot of variables at different phases in their cycles also lie roughly on a line of similar slope, it seems likely that the trajectory of a star with increasing

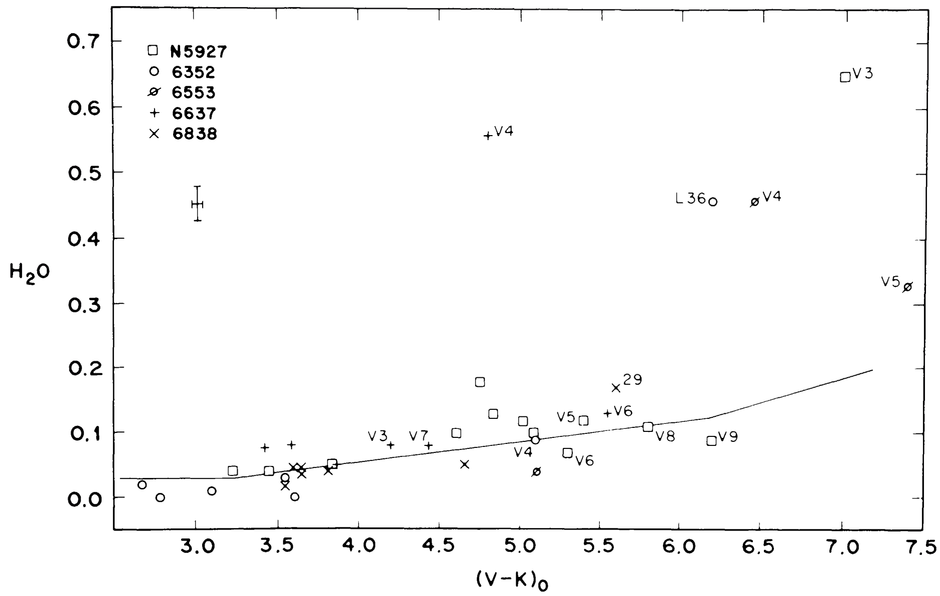


FIG. 2.—H_2O indices for stars in the most metal-rich clusters (group A). The mean line for field giants is from Aaronson, Frogel, and Persson (1978). Variables and a few peculiar stars, some of which are from other metallicity group clusters, are marked.

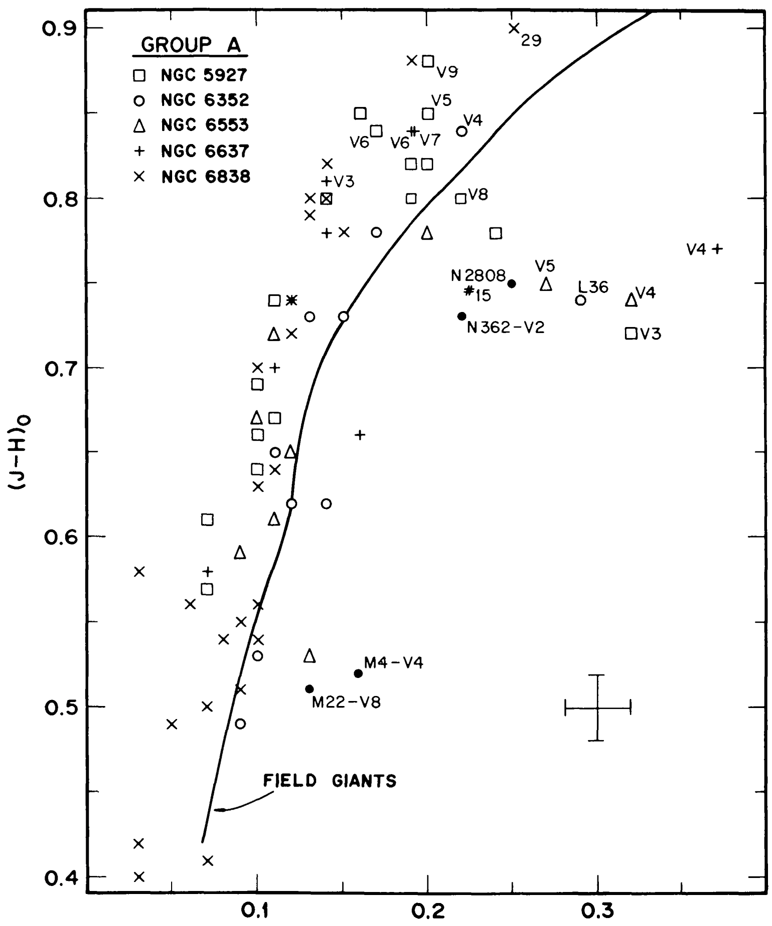


FIG. 3.—$(J-H)_0$, $(H-K)_0$ plot for stars in the group A clusters, except 47 Tuc. Variable stars are marked. Variables from clusters in other groups are also plotted when they lie in unusual places.

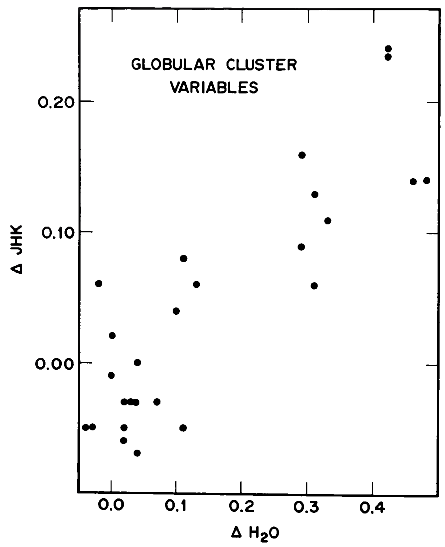


FIG. 4.—ΔJHK measures the displacement of the variables from the mean field line along a line of slope 45° with respect to the axes of a plot like Fig. 3. ΔH_2O measures the displacement upward from the mean field line in Fig. 2. In both cases the units are magnitudes. A negative ΔJHK means that that star lies above and to the left of the mean field line. The more extreme 47 Tuc variables (Fig. 8 of GC5) are included in this figure.

H_2O absorption is a line whose slope is close to -0.65. Thus, the J magnitudes are also being affected by H_2O absorption (or some other molecular constituent) but by a somewhat different amount than the K magnitudes. If the slope were exactly -1.0, then the H_2O absorption within the J and K bandpasses would be identical, and the $J-K$ color would be unchanged. But there is no *a priori* reason to expect this, while the evidence of Figure 3 suggests that H_2O absorption within the J filter is smaller than within the K filter. We conclude that the $J-H$ and $H-K$ colors are certainly not useful, and $J-K$ colors may not be reliable, as temperature indicators for very cool stars and variables unless the effects of H_2O absorption can be removed.

c) $(J-K)_0, (V-K)_0$ *Colors*

Figures $5a$–$5c$ show the relation between $(J-K)_0$ and $(V-K)_0$ colors for stars in clusters of three of the five metallicity groups. The mean field giant line is from FPAM. The cluster line is defined by stars in M3, M13, M71, and M92, and is consistent with the 47 Tuc giants as well (GC5). Consider first groups B and C2. Clusters with the best optical photometry and the lowest probability of having large reddening uncertainties, specifically the five just noted plus NGC 288 (and NGC 6397 and 6752, which are not shown), display little scatter and lie along a common sequence. Most of the other clusters, though, scatter considerably about the two mean lines, with the displacements from the mean lines often being systematic for all stars in a given cluster as occurs for NGC 2808 (in Fig. $5b$) and 4372 (in Fig. $5c$). Since most of the scatter occurs in the region where the reddening vector is parallel to the mean lines, its source could be due to a true scatter in the relationship between the intrinsic colors for the metal-poor clusters. A more likely explanation, discussed in GC9, is that there are systematic errors in the V photometry, amounting to typically 0.1–0.3 mag for some of the clusters. Figures analogous to Figures $5a$–$5c$ can serve as diagnostics for identifying clusters with such systematic errors.

The metal-rich, group A clusters (in Fig. $5a$) also show considerable scatter. In most cases, though, there is evidence for large and variable reddening across the face of these clusters, and crowded fields and varying background light may introduce significant errors into the traditional methods of doing optical photometry. Nevertheless, note that redder than $V-K_0 = 4.5$ there is a sequence of stars in Figure $5a$ which lies to the *blue* in $(J-K)_0$ of the mean field line. This is not what would have been expected on the basis of the data available at the time that our work on 47 Tuc was completed (GC5) and contributes to the temperature scale problems as discussed in the next section.

V. TEMPERATURES, LUMINOSITIES, AND MEAN COLOR RELATIONS

Our technique for calculating effective temperatures and bolometric luminosities for globular cluster stars has been discussed in GC5. Here we will examine the new results for consistency and give some cautionary remarks. We also wish to rediscuss the mean relations between *VJHK* colors given in FPAM because of their importance for the temperature scale and to comment on some disagreements between our conclusions and those of Aaronson and Mould (1982).

a) *The Zero Point of the K Magnitude Scale*

The zero point of the K magnitude scale is defined by setting $K(\alpha$ Lyr$) = 0.00$. On Johnson *et al.*'s (1966) scale, $K(\alpha$ Lyr $= +0.02$. If the three supergiants in Cygnus and stars with $(J-K)_J > 1.4$ are excluded, there are 24 stars in common between Tables 10 and 11 of FPAM and the photometry of Johnson *et al.* (1966) and Lee (1970). For these stars,

$$K_{\rm CIT} - K_{\rm J} = -0.003 \pm 0.008.$$

Thus, there is no evidence for a systematic difference between the CIT and Johnson K magnitude scales. Aaronson and Mould's (1982) statement to the contrary is incorrect, and there is no need to apply the 0.02 mag correction to the K magnitudes as they suggested. The 0.02 mag offset between α Lyr and the 24 comparison stars could reflect a color transformation between the effective photometric bandpasses for red and blue stars in Johnson's system. Such a color term is not at all surprising in view of the different detectors, field lenses, and filter transmission functions used by Johnson, Lee, and us.

b) *The JHK Colors*

Because only a limited amount of stellar data were available, the mean relation between $V-K$ and $J-K$ in FPAM was taken from Johnson (1966), as modified by Lee (1970) for the M giants, with the $J-K$ colors transformed to the CIT system. Unfortunately, the transformation was given in terms of J magnitudes at a given $(J-H)_{\mathrm{CIT}}$ color. This is of limited use because Johnson *et al.* (1966) do not give $J-H$ colors. The transformation was therefore rederived using the sample of 24 stars mentioned above. The least squares fit is

$$(J-K)_{\mathrm{CIT}} = 0.908(J-K)_{\mathrm{J}} + 0.007, \qquad (1)$$

with a dispersion of 0.05 mag. If this transformation is applied to the mean colors of Johnson (1966) and Lee (1970), the colors given in Table 12 of FPAM are recovered. *Thus, the mean $V-K$, $J-K$ relation in that table is equivalent to that given by Johnson (1966) and Lee (1970).*[4] The statement made by Aaronson and Mould (1982) about a systematic error in the transformation is therefore incorrect.

The mean relation between $(J-H)_0$ and $(H-K)_0$ in Table 12 of FPAM could not be based on the extensive data of Lee (1970) since there are only a few stars in common, and from these few there is an indication of systematic differences as great as 0.05 mag between the $H-K$ colors in the two systems. Thus, since it is based on the rather limited data in Tables 10 and 11 of FPAM and some unpublished data, the mean $(J-H)_0$, $(H-K)_0$ relation should be regarded as being somewhat uncertain.

c) *The Bolometric Corrections*

As discussed in GC5, bolometric luminosities for globular cluster giants are calculated by integrating un-

[4] The transformation between the CIT and the Anglo Australian Observatory systems (Elias *et al.* 1983), the latter of which is equivalent to Johnson's $J-K$ colors (Jones and Hyland 1982), has a slope of 0.90, not significantly different from that in eq. (1).

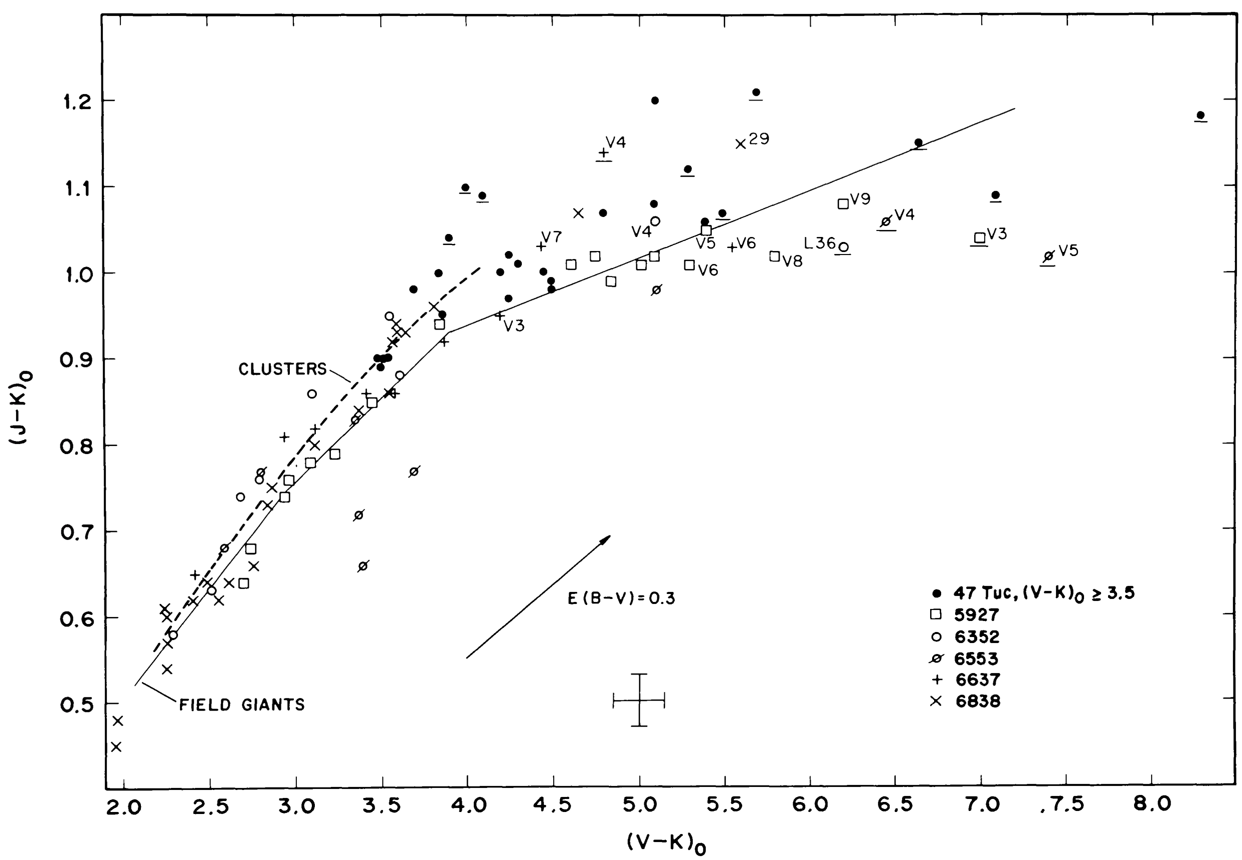
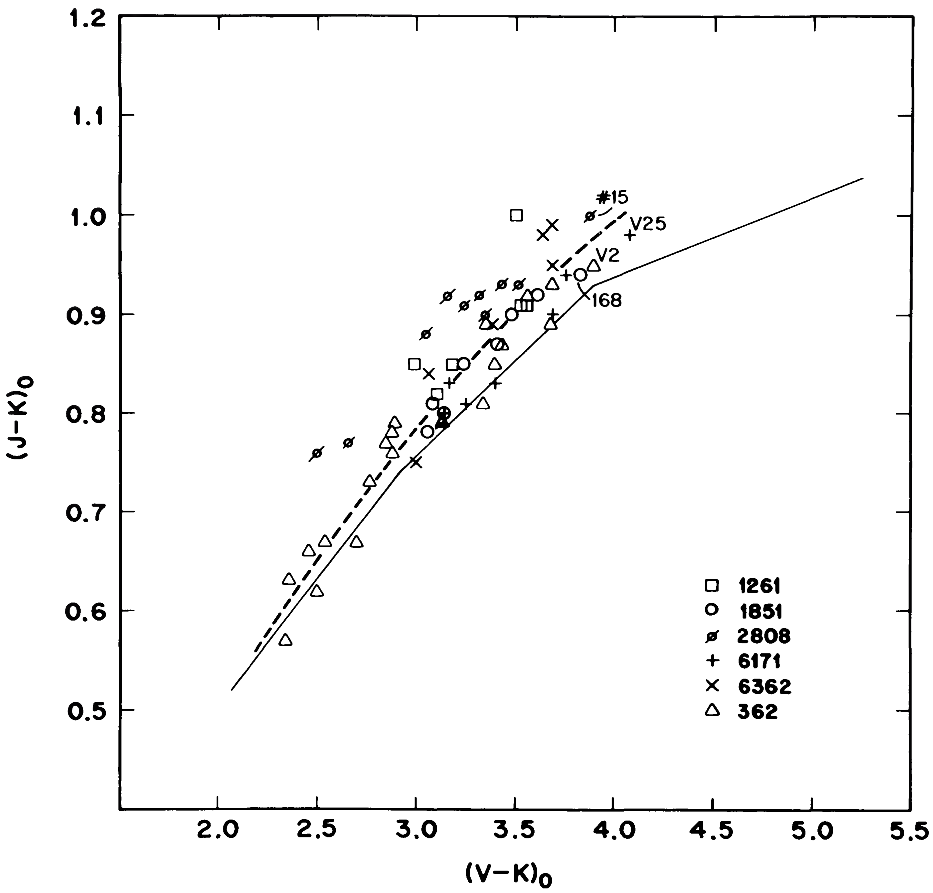


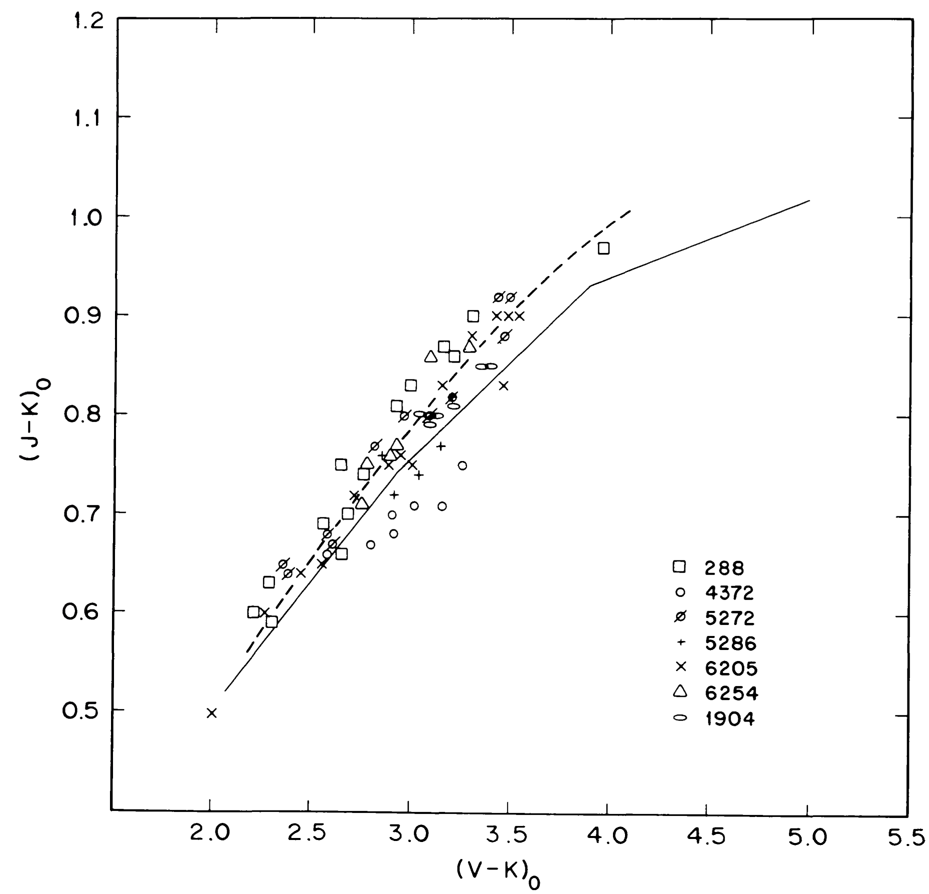
FIG. 5*a*

FIG. 5.—(*a*)–(*c*) $(J-K)_0$ is plotted against $(V-K)_0$ for clusters in three of the five metallicity groups. Stars from 47 Tuc (GC5) are plotted only if $(V-K)_0 \geq 3.5$. Some of the variables are labeled. Solid line is the mean relation for field giants from Johnson (1966) and Lee (1970) as transformed to the photometric system in Frogel *et al.* (1978). Dashed line is the mean relation for M3, M13, M92, and M71. Underlined symbols indicate stars with excess H_2O absorption for their $(V-K)_0$ color.



1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
(J−K)$_0$
#15
V25
V2
168
1261
1851
2808
6171
6362
362
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
(V−K)$_0$

FIG. 5*b*



1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
(J−K)$_0$
288
4372
5272
5286
6205
6254
1904
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
(V−K)$_0$

FIG. 5*c*

der the reddening corrected energy curves. The present data add 13 new stars with $(V-K)_0$ between 5.0 and 7.4, doubling the number previously available in this color range. The dependence of BC_K on $(V-K)_0$ for these is consistent with the mean line drawn in Figure 11 of GC5.

A cautionary remark is that the strong H_2O absorption could cause the bolometric luminosities to be overestimated by our technique. However, we note that at a given $(V-K)_0$ there is no systematic difference in the *calculated* values of BC between the stars with relatively strong and weak H_2O absorption.

d) *Effective Temperatures*

For nonvariables or for small-amplitude variables with $(V-K)_0 < 7.0$, the temperature scales of Ridgway *et al.* (1980) and of GC1 are the best available for low metallicities, as discussed in GC5. Two points should be emphasized: first, except at the very cool end of the GC1 scale where the neglected effects of molecular absorption became important, *the two scales are completely consistent with one another*; second, although the Ridgway *et al.* (1980) scale is derived from observations of stars with near solar metal abundance, essentially all of the nonvariables and small-amplitude variables in the metal-poor clusters have $(V-K)_0 < 4.0$, so that the effects of molecular absorption should be small. If $V-K$ colors are not available, then $J-K$ should be a good temperature indicator for metal-poor stars with $T_{\rm eff} >$ 4000 K, in which regime $J-K$ is reasonably sensitive to the changes in $T_{\rm eff}$ and the models of GC1 are consistent with the *observed* $V-K$, $J-K$ relationship.

The most serious temperature scale problem concerns the treatment of large-amplitude variables and cool stars lacking $V-K$ colors or having $(V-K)_0 > 7.0$. It has been argued (e.g., Aaronson and Mould 1982, and references therein) that for stars without $V-K$ data, $J-K$ colors should be used to predict $V-K$, and these entered into the Ridgway *et al.* (1980) calibration for T_e. For large-amplitude variables, a number of authors (e.g., Fox 1982) have argued, on the basis of a very small number of occultation measurements, that a blackbody temperature scale calibrated against $J-K$ provides a good estimate of effective temperature. We, on the other hand, have emphasized the relatively large and unpredictable effects of blanketing on $J-K$ compared to $V-K$ (GC5) given the lower sensitivity of $J-K$ to changes in $T_{\rm eff}$.

The estimation of effective temperature from $J-K$ colors alone for cool stars or for large-amplitude variables has several problems. As shown in Figures 5*a*–5*c*, there is a significant amount of scatter in $J-K$ at a given $V-K$ for cluster stars, and how one transforms from $J-K$ to $V-K$ seems less and less clear; the transformation may depend on metallicity. We pointed out in GC5 that for the reddest stars in 47 Tuc, the amount of TiO absorption, which certainly affects $V-K$, was not significantly different from that found in field stars. This supported our contention that the values of $T_{\rm eff}$ for these stars were on the same system as the Ridgway scale, which is also based on field stars. The spread in the $V-K$, $J-K$ relation now indicates that the situation is more complex, with TiO appearing to be more important in the metal-rich clusters than in 47 Tuc. However, given the near insensitivity of $J-K$ to temperature changes in the region of interest, we feel unable at present to derive physically meaningful effective temperatures for the coolest stars or the large-amplitude variables from $J-K$ colors.

Although it is derived from nonvariable, metal-rich stars, we have employed the Ridgway *et al.* (1980) scale to get $T_{\rm eff}$ from $V-K$ for cluster variables since it seems to us to be the least objectionable of the several alternatives, particularly because of the insensitivity of $T_{\rm eff}$ to reasonable variations in $V-K$—an uncertainty of ± 0.5 mag in $V-K$ effects $T_{\rm eff}$ by less than 100 K. The Dyck, Lockwood, and Capps (1974) scale has been employed for $V-K > 7$ (Fig. 12 of GC5 shows that it fits smoothly onto the Ridgway *et al.* 1980 scale), again mainly because it seems to be the least objectionable alternative. Additional occultation angular diameters for the coolest stars are urgently needed to resolve the uncertainties in the temperature scale for cool stars.

VI. COMMENTS ON INDIVIDUAL CLUSTERS

We comment here on a number of the most thoroughly observed clusters. *C-M* diagrams and the CO distributions for stars in these clusters will be presented in order to illustrate the high quality of the data and to serve as examples of a number of points made above. We assume that the giant branch locations follow both conventional wisdom and the theoretical calculations of stellar evolution, so that redder giant branches imply higher metallicity. The metallicity dependence of globular cluster giant branches in the H-R diagram is discussed fully in § III of GC9.

a) *The Metal-rich Clusters NGC 5927 and 6637 (M69)*

C-M diagrams for the two metal-rich clusters NGC 5927 and 6637 (M69) are shown in Figure 6. While the giant branch of NGC 5927 lies close to that of 47 Tuc, M69's giant branch lies considerably to the blue—consistent with Cohen's (1983) ranking but not with Zinn's (1980) since he puts M69 more metal rich than 47 Tuc by 0.25 dex. (Mould, Stutman, and McElroy 1979 also rank M69 as more metal rich than 47 Tuc.) However, the location of NGC 5927 could well be affected by uncertainties in its large, and spatially variable, reddening (Menzies 1974). A decrease in the reddening would move the giant branch of NGC 5927 more to the right

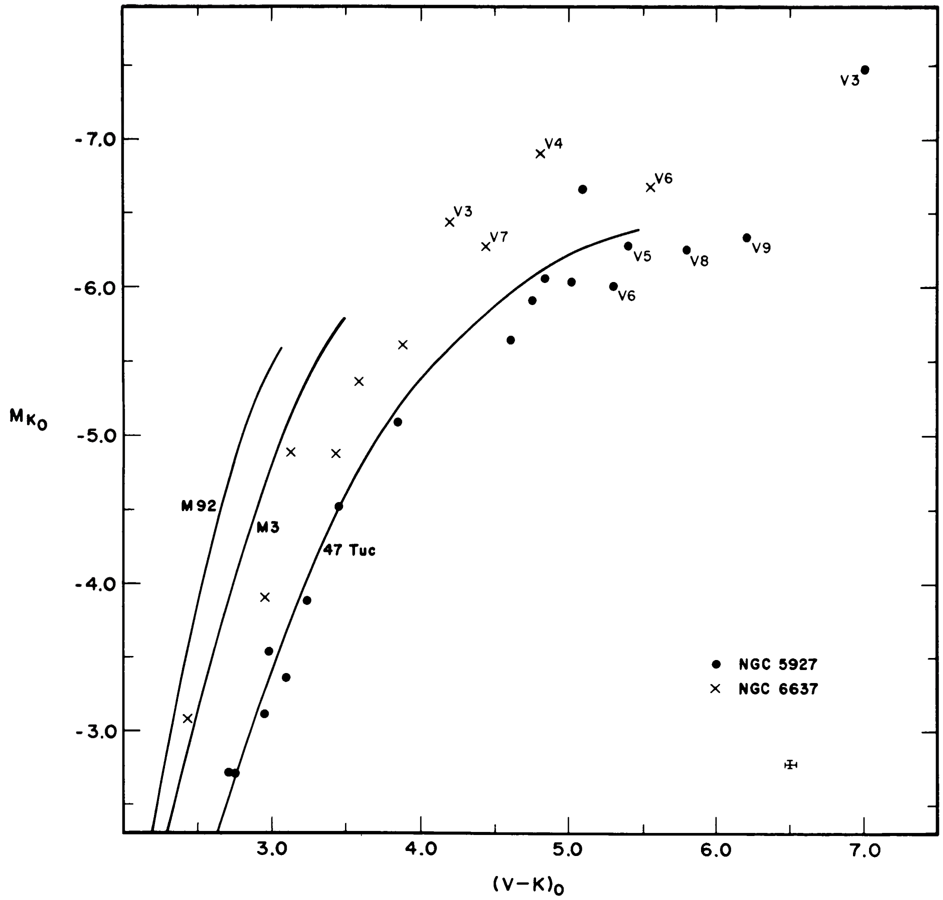


FIG. 6.—Infrared *C-M* diagram for NGC 5927 and 6637

of 47 Tuc's while at the same time making it somewhat brighter. The nonvariable star which is 0.5 mag brighter than the giant branch may not be a member of the cluster. Note the location of the two long-period variables: V3 in NGC 5927 and V4 in NGC 6637.

The CO strengths of the stars in the two clusters are shown in Figure 7. The scatter is similar to that in NGC 6838 (GC2) and 47 Tuc (GC5), although in NGC 5927 the mean CO strength is comparable to that of the field giants and is stronger than in 47 Tuc.

b) *NGC 6171 and 6362*

Pilachowski, Sneden, and Green (1981) claimed that these two clusters have the same metallicities, to within ± 0.1 dex, as 47 Tuc and M5. A sufficient number of stars was observed in each cluster to define the upper part of their giant branches (GBs). Figure 8 is a *C-M* diagram for the stars in the two clusters with parts of the fiducial GBs for 47 Tuc and M3 (GC1; GC5) indicated. While the GBs of NGC 6171 and 6362 are similar to one another, this figure illustrates how divergent they are from that of 47 Tuc and also that of M3 which is very similar to that of M5 (see Fig. 12*a*).

c) *NGC 2808*

The *C-M* diagram of NGC 2808 is shown in Figure 9*a*. The spread of nearly a magnitude in $(V-K)_0$ at constant M_{K_0} could arise from a combination of large random errors in the V photometry, which seem to have occurred as discussed in § IV*c*, and field star contamination. The $(J-K)_0 - M_{K_0}$ plot shown in Figure 9*b* also shows a significant spread. This cluster is discussed more fully in the appendix in GC9.

d) *NGC 288 and 362*

On Zinn's scale, NGC 288, a cluster with an extremely blue horizontal branch, is assigned a metallicity nearly 0.5 dex less than that of NGC 362, a cluster with a red horizontal branch. In contrast to this, Cohen's (1982) spectroscopically determined abundance scale indicates that NGC 362 is slightly (0.05 dex) more metal poor than NGC 288. As shown in Figure 10, the GBs of NGC 288 and 362 are quite close to one another (NGC 288's being a bit redder), in good agreement with Cohen's (1982) ranking. Both clusters are somewhat metal poor —their GBs are much more similar to that of NGC

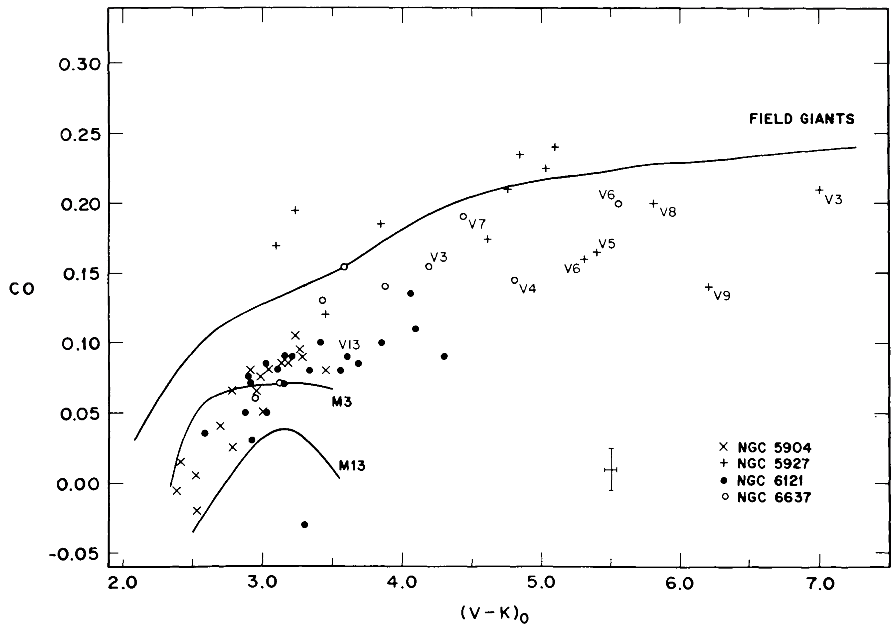


FIG. 7.—CO index, plotted against $(V-K)_0$ for stars in four clusters

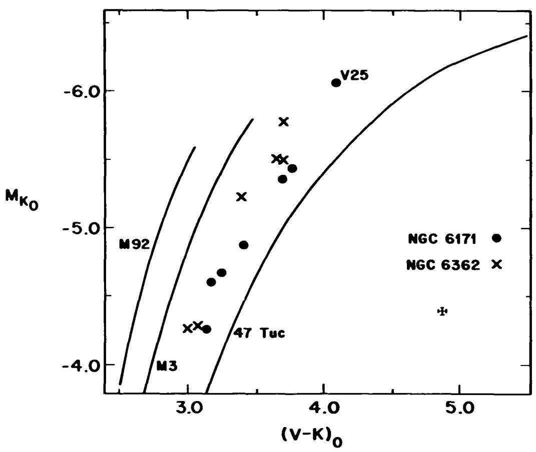


FIG. 8.—Infrared *C-M* diagram for NGC 6171 and 6362

5272 (M3) than to 47 Tuc's. There is, however, a scatter in color shown by the NGC 362 giants—even when the optically selected asymptotic giant branch (AGB) stars are ignored—which extends to the top of the GB. NGC 288's GB is, by contrast, essentially dispersionless. Other examples of dispersionless GBs with which to contrast that of NGC 362 are those of NGC 6397 and 6752. The difference in dispersion of stars along the GBs of the two clusters is, if anything, even more obvious in the M_{K_0}, $(J-K)_0$ plot of Figure 10*b*. The relative displacements of the NGC 362 giants in $(J-K)_0$ are closely correlated with those in $(V-K)_0$, which makes it unlikely that the dispersion arises from photometric errors.

The NGC 362 giants appear to have considerably more scatter in CO absorption than do the NGC 288 stars. This is illustrated in Figure 11. In fact, as is pointed out in GC9, NGC 362 and 6656 (M22) have the two largest CO spreads of all the clusters in the sample. As Figure 11 shows, the increased spread in CO for NGC 362 compared to NGC 288 is due to the four stars in NGC 362 with CO values at or below the mean M13 line, and to V2. The NGC 362 stars also have more scatter in a $(J-H)_0$, $(H-K)_0$ plot than do the stars in NGC 288.

The spread in color at constant luminosity and in CO absorption at a given color in NGC 362 as compared to NGC 288 may result from a small spread in heavy element abundances in NGC 362. McClure and Norris (1974) raised this possibility on the basis of a scatter they observed in their DDO indices.[5] It is also possible

[5]Unfortunately, there is only one star in common between our sample of giant branch stars in NGC 362 and that of McClure and Norris (1974).

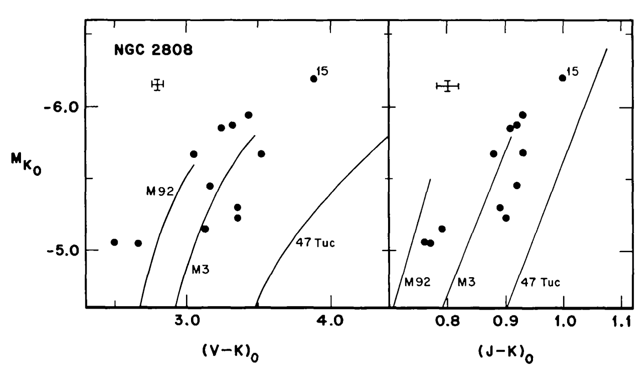


FIG. 9.—Two infrared *C-M* diagrams for NGC 2808. In the left panel $(V-K)_0$ is shown as a function of M_{K_0}, while the right panel displays $(J-K)_0$.

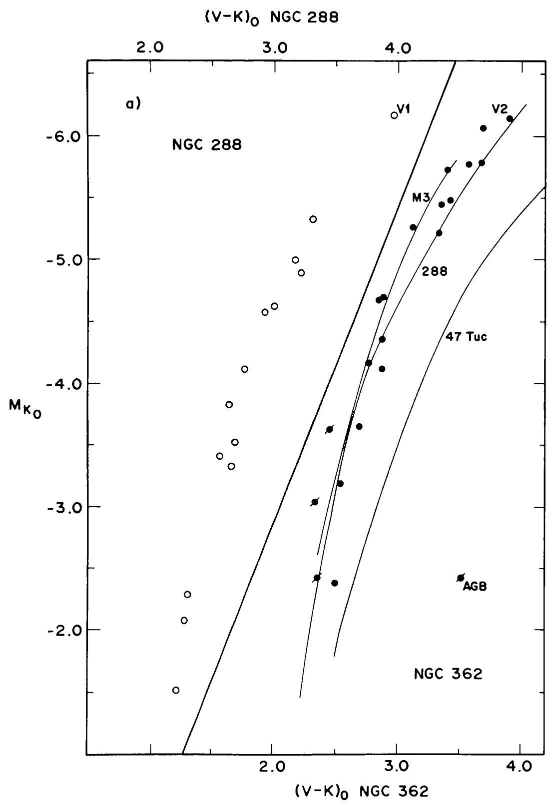


FIG. 10a

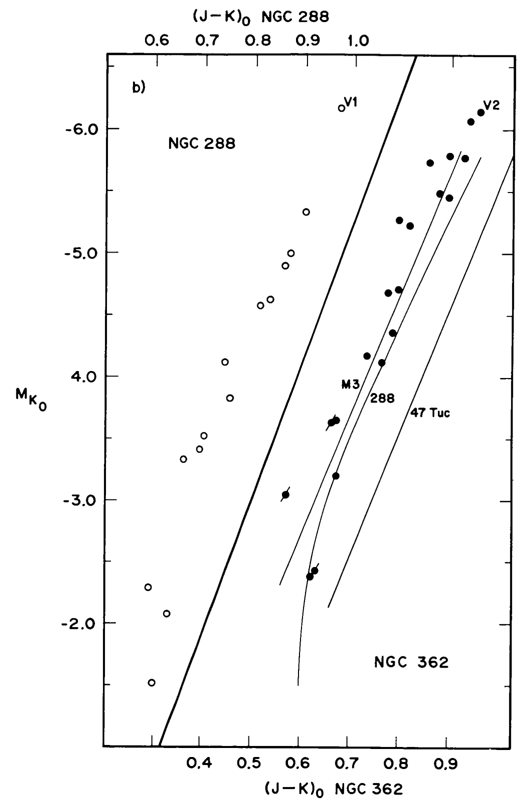


FIG. 10b

FIG. 10.—(*a*) Infrared *C-M* diagram for NGC 288 and 362. The optically identified asymptotic giant branch stars are indicated by a bar through the appropriate symbol (*open circles*, NGC 288; *filled circles*, NGC 362). Solid lines in the right half of the figure denote the mean giant branches for NGC 288, M3, and 47 Tuc. Error bars are the size of the symbols. (*b*) Same as (*a*), except $(J-K)_0$ is plotted instead of $(V-K)_0$.

that the AGB in NGC 362 is, for some as yet unknown reason, abnormally displaced from the GB even close to the GB tip.

What about the effects of molecular blanketing on the colors and CO indices? The NGC 362 stars do show a significant range in CN absorption at constant temperature (color), as pointed out in the Appendix to this paper and by McClure and Norris (1974). There is even a possible anticorrelation between CO and CN in NGC 362 (see the Appendix), reminiscent of that found in 47 Tuc. However, the 47 Tuc GB is tight, so that such a range in molecular absorption could not account for the spread in NGC 362's GB.

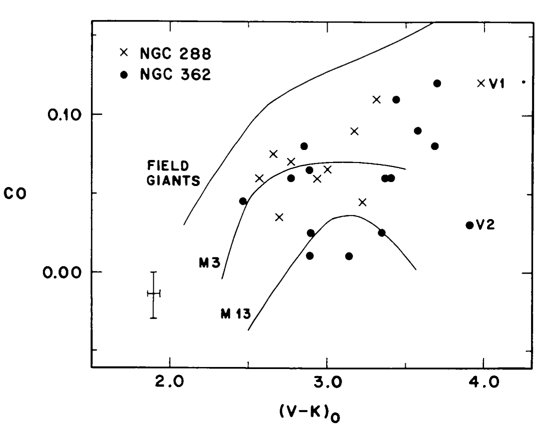


FIG. 11.—CO index is plotted against $(V-K)_0$ for stars in NGC 288 and 362.

The relative differences in location of the GBs of the two clusters in $(V-K)_0$ and $(J-K)_0$ is puzzling. If the stars on the blue side of NGC 362's GB are AGB stars, than the ridge lines for this cluster which we have drawn would become quite close to those of NGC 288. We find it rather curious that while many clusters have apparently well defined AGBs, a few do not, even though both the infrared and optical photometry is of high enough accuracy that the scatter in the giant stars observed is quite small. An example is NGC 288. Perhaps its HB is so sparse and so exceptionally blue (see Cannon 1974; Alcaino 1975) that the relative numbers of stars that get fed up the AGB is small compared to other clusters.

e) *M3, M4, and M5*

The close similarity of the optical *C-M* diagram of M5 and M3 was pointed out by Arp (1962).

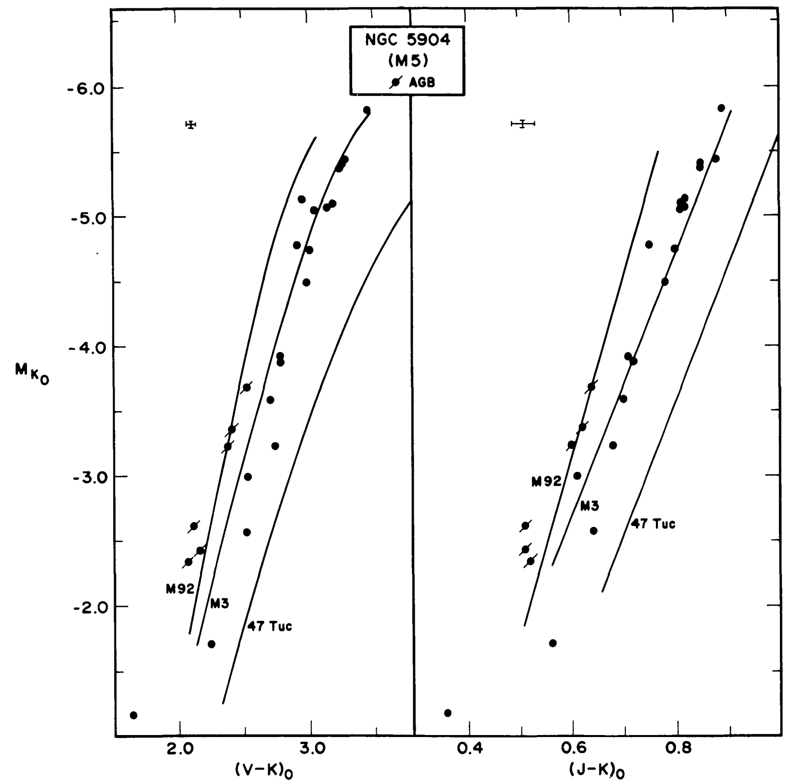


FIG. 12*a*

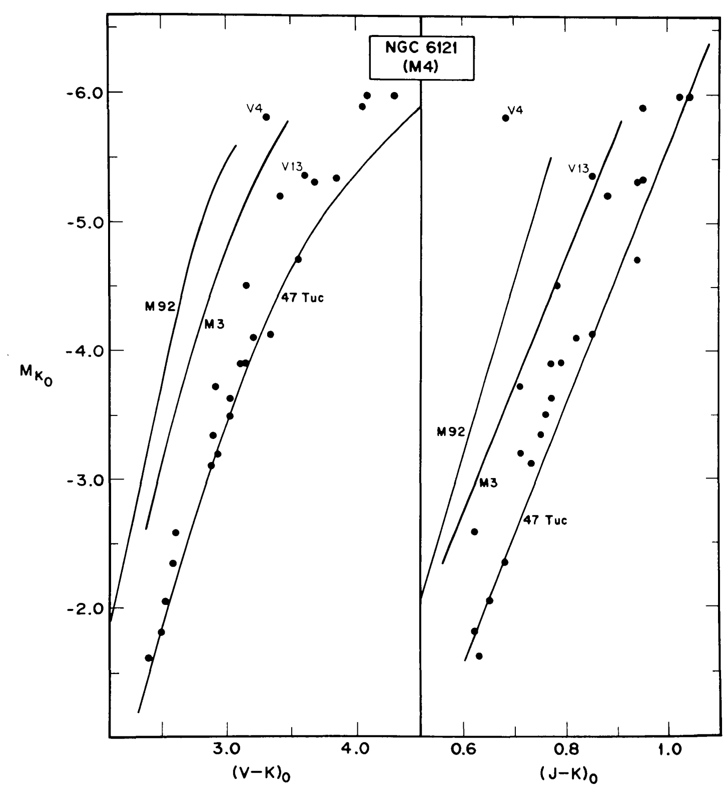


FIG. 12*b*

FIG. 12.—(*a*) *C-M* diagram for both $(J-K)_0$ and $(V-K)_0$ of M5 is shown. (*b*) Same as (*a*) for M4. Optically selected asymptotic giant branch stars are indicated by a bar.

Zinn assigns them metallicities within 0.1 dex of each other, and, from high resolution echelle spectroscopy, Pilachowski, Wallerstein, and Leep (1980) assigned [Fe/H] values of -1.55 and -1.33 to M3 and M5, respectively. These values are consistent with our results and Zinn's (1980) scale. This similarity extends to the infrared, as is evident from inspection of Figure 12*a*. Recently, however, Pilachowski, Sneden, and Green (1981) have published a revised abundance of -1.1 for M5 on a scale that puts [Fe/H] for 47 Tuc at -1.0. This is clearly not consistent with the present results nor with Cohen's (1982) most recent spectroscopic study of the two clusters. We also note that Searle and Zinn's abundance for M5, -1.15 on a scale which puts M3 at -1.67, is not consistent with our data either. Finally, metallicity estimates derived from RR Lyrae data are -1.01 and -1.57 for M5 and M3, respectively (Butler 1975), although only a very few stars could be observed in M5.

AGB stars, picked out from optical photometry, are clearly separated from GB stars in both $(V-K)_0$ and $(J-K)_0$ for M5. The scatter in both colors about a mean line for only the GB stars is consistent with observational uncertainties alone.

Infrared *C-M* diagrams for NGC 6121 are shown in Figure 12*b*. The GB is close in both $(V-K)_0$ and $(J-K)_0$ to that of 47 Tuc. The steepness of the GB of M4, the lack of curvature at the bright end, and the absence of very red stars (as can be seen by comparing Fig. 12*b* to the GBs of the metal-rich clusters in Fig. 6) suggest that M4 is somewhat more metal poor than 47 Tuc. The distribution of CO with $(V-K)_0$ in M4 shown in Figure 7 is also closer to that of an intermediate metallicity cluster rather than a metal-rich one. The simplest explanation for this situation, and one advocated from evidence presented in § IV*a* and in GC9, would be that $E(B-V)$ for M4 is 0.1 mag greater than we adopted here, even though a number of values of $E(B-V)$ in the recent literature, based on independent work as well as on summaries of existing determinations, cluster around 0.35 to 0.37 (e.g., Zinn 1980; Harris and Racine 1979; Cacciari 1979; Sturch 1977). In contrast, though, Newell (1970) derives $E(B-V)=0.45\pm0.03$ from HB stars, and Kron and Guetter (1976) give 0.49 from their multicolor photometry. Mould, Stutman, and McElroy (1979) also require a large $E(B-V)$ for consistency with their metallicity parameter. This matter is discussed more fully in the Appendix to GC9.

Even aside from the variables, Figure 12*b* shows that the upper part of the GB of M4 exhibits more scatter in both $(V-K)_0$ and $(J-K)_0$ than does the lower part. Sandage (1981) and Sturch (1977) have both concluded from RR Lyrae observations that there is a real variation in $E(B-V)$ across the cluster of ±0.03 to 0.04 mag. The brighter stars with IR data are drawn from zones 2–6 of Lee (1977), and hence from a much greater area than the faint ones which are from the inner zone only, and thus are much less likely to be affected individually by spatially varying extinction. Since an rms scatter of ±0.03 to 0.04 mag in $E(B-V)$ is equivalent to ±0.1 in $E(V-K)$ and 0.02 in $E(J-K)$, this scatter is adequate to explain the appearance of the upper GB in Figure 12*b*.

f) *NGC 6397 and 6752*

Since these clusters lie in relatively uncrowded fields and their giants are bright, they have been the subjects of a number of detailed studies—e.g., Bell, Dickens, and Gustafsson (1979), Bell and Dickens (1980), Norris *et al.* (1981), Da Costa and Cottrell (1980), and Mallia (1978). The infrared *C-M* diagrams for the two clusters are shown in Figure 13. Once more, the visually selected AGB stars are well separated from the rest in $(V-K)_0$. The adherence of the giant stars in both clusters to a smoothly drawn ridge line is so outstanding that they may be taken as paradigms for dispersionless GBs in globular clusters and clearly demonstrate that, given data of sufficient quality, observations of only a handful of stars are needed to delineate the GB.

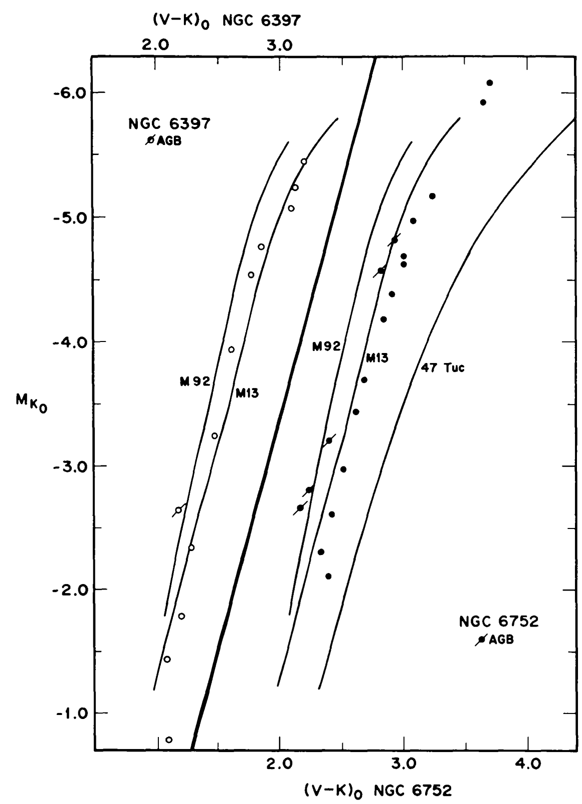


FIG. 13.—*C-M* diagrams of NGC 6397 and 7652. Optically selected asymptotic giant branch stars are indicated by a bar through the appropriate symbol (*open circles*, NGC 6397; *filled circles*, NGC 6752).

The beauty of the *C-M* diagrams for these clusters not withstanding, there is a problem in the interpretation of the infrared data. Although the GBs are close to one another in $(V-K)_0$, they are significantly separated in $(J-K)_0$. The lack of internal scatter in the data and the fact that both sets of optical data were obtained by the same observer (Cannon 1974; Cannon and Stobie 1973) lead us to discount the possibility of photometric errors.

g) NGC 6656 (M22)

This cluster has been compared in the literature to ω Cen (e.g., Hesser, Hartwick, and McClure 1977), with the implication that its members possess a spread in heavy element abundances, although perhaps not as large as that of ω Cen. Figure 14 is an infrared *C-M* diagram for the 19 giants observed. If the variables are excluded, the width of the GB is seen to be small and probably no larger than that of NGC 362 (Fig. 10*a*). Considering the low latitude and large reddening for this cluster $[E(B-V)=0.36]$, we believe that a probable explanation for whatever scatter is present is variable reddening à la NGC 6121 (M4) and NGC 3201 (GC6). The presence of variable reddening is demonstrated by Cohen's (1981) observations of the interstellar lines in the spectra of M22 giants. Lloyd Evans (1978) has demonstrated that most of the GB scatter originally observed in the optical could be accounted for by field star contamination and observational errors. Manduca and Bell (1978) find "no evidence for star to star variations in metal abundance in M22" from an analysis of RR Lyrae data, although Pilachowski *et al.* (1982) again claim a large spread in metallicity exists in M22. Recently, Norris and Freeman (1983) detected a spread in [Ca/H] of 0.3 dex, probably corresponding to a spread in [Fe/H] of less than 0.2 dex, from analyzing spectra of 100 members of M22. Given the definite presence of variable reddening within the cluster, our *C-M* diagram is not inconsistent with Norris and Freeman's claimed spread, but cannot be used to support it.

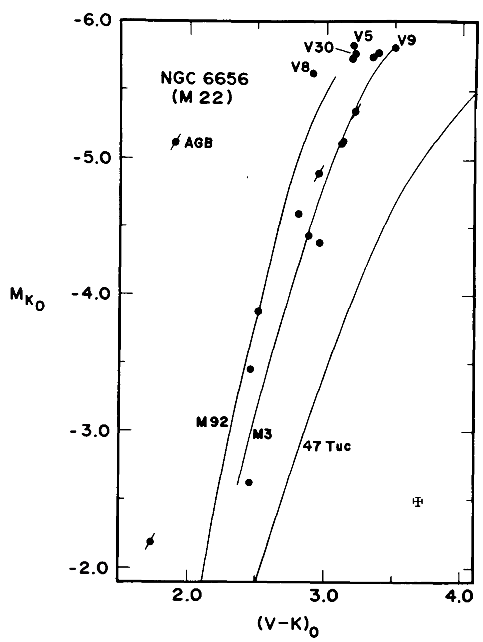


FIG. 14.—*C-M* diagram of M22

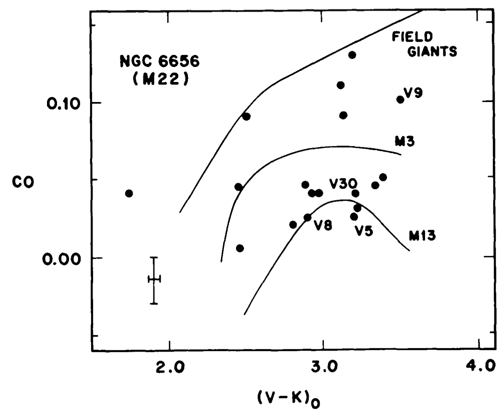


FIG. 15.—CO index, plotted against $(V-K)_0$ for stars in M22.

The blue location of the GB of M22 in $(V-K)_0$ and $(J-K)_0$ is consistent with the low abundance assigned to the cluster by Cohen (1981) from echelle spectra (-1.8) and by Manduca and Bell (1978) from RR Lyrae variables (-1.6).

In contrast to the appearance of the *C-M* diagram, which we have argued is determined principally by the abundance of elements *heavier* than the CNO group (GC5; GC9), the CO absorption in the M22 giants shows a variation at constant color comparable to that observed in ω Cen (Fig. 15). M22 also has a tremendous range in CN strengths, as discussed in the Appendix.

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APPENDIX

CH AND CN DATA

Additional data on molecular band strengths in globular cluster giants are required in the companion paper (GC9) to determine whether the presence of a large range in CN strengths within a particular cluster is correlated with any property of the cluster as a whole. A set of moderate dispersion optical spectra of globular cluster giants, obtained for another purpose, is described in detail in GC7. From these spectra, supplemented by additional observations with the same type of detector on the 5 m Hale telescope, we can measure, as described in Cohen and Frogel (1982), parameters which characterize the strength of the absorption at 4300 Å due to CH and near 4180 Å from CN. The resulting CN and CH indices are listed in Table 30. The uncertainties in our indices, based on the small number of stars observed twice, are ± 0.015 for I(CH) and ± 0.04 for I(CN). The measurements of I(CN), the absorption of the 4100 Å CN band, are related by a well-defined linear transformation to the values of $C(41-42)$ (defined using the DDO filters) determined for the stars in common in NGC 362 by McClure and Norris (1974) and in 47 Tuc by Norris and Freeman (1979).

For the stars in NGC 362 (excluding V2) there is a hint of the bimodal behavior of CN absorption which has now been found in several globular clusters (47 Tuc by Norris and Freeman 1979, M71 and NGC 3201 by Smith and Norris 1982, M4 by Norris 1981, and NGC 6752 by Norris *et al.* 1981), but the data are fragmentary. There is also evidence for an anticorrelation between CO and CN absorption in these stars, as was found for 47 Tuc by GC5 and for M71 by Smith and Norris (1982), and for an anticorrelation between CN and CH absorption, as seen in several of these clusters.

TABLE 30

CH and CN Indices

Cluster	Star	I(CH)	I(CN)	Cluster	Star	I(CH)	I(CN)
NGC 104	7320	−0.01	+0.05	NGC 3201 ...	1117	+0.22	+0.02
(47 Tuc) ...	1407	+0.19	+0.14		1309	+0.18	−0.03
	1412	+0.05	0.00		1312	+0.25	+0.08
	1421	+0.15	−0.04		1314	+0.24	0.00
	2426	+0.23	+0.18		1410	+0.24	+0.03
	3407	+0.25	+0.16				
	4418	+0.18	+0.09	NGC 5904 ...	I-4	+0.24	+0.04
	6408	+0.21	+0.08	(M5)	I-20	+0.30	+0.12
	5529	+0.24	+0.04		I-25	+0.25	+0.06
					I-55	+0.15	+0.04
					II-9	+0.28	+0.16
NGC 288	C19	+0.23	−0.02		III-53	+0.20	−0.04
	A77	+0.19	+0.04		III-56	+0.24	0.00
	A80	+0.25	+0.03				
	A96	+0.25	+0.09	NGC 6121 ...	3413	+0.27	+0.10
	A245	+0.22	+0.05	(M4)	3713	+0.32	+0.11
	A260	+0.14	+0.08		4633	+0.29	+0.12
				NGC 6656 ...	I-12	+0.18	+0.01
NGC 362	I-2	+0.21	+0.02	(M22)	I-80	+0.24	+0.15
	I-23	+0.28	+0.08		I-82	+0.14	−0.03
	I-44	+0.28	+0.08		II-62	+0.18	+0.10
	I-52	+0.28	0.00		III-3	+0.18	+0.10
	II-40	+0.29	+0.05		III-12	+0.17	+0.13
	II-43	+0.26	0.00		III-52	+0.21	+0.11
	II-47	+0.17	+0.05		III-75	+0.20	−0.04
	II-49	+0.30	+0.01		III-106	+0.23	+0.19
	III-4	+0.31	+0.06		IV-20	+0.21	+0.18
	III-11	+0.26	+0.02		IV-99	+0.24	+0.12
	III-25	+0.31	+0.03		IV-102	+0.14	+0.06
	III-37	+0.27	−0.02				
	III-39	+0.27	+0.04	NGC 7078 ...	I-12	+0.17	+0.02
	III-44	+0.28	+0.08	(M15)	II-29	+0.16	+0.01
	III-63	+0.28	+0.14		II-64	+0.10	+0.01
	III-70	+0.24	+0.06		II-75	+0.11	+0.02
	V2	+0.32	+0.04		S6	+0.11	+0.02

Bimodal behavior with N enhanced and C depleted has also been discovered in M3 and M13 by Suntzeff (1981), while more complex C and N variations are seen in M92 by Carbon *et al.* (1982).

Of the three stars with the strongest CN absorption, one is a member of 47 Tuc and the other two are in M22, a quite metal-poor cluster. M22 shows an extremely large range in CN strength at a given temperature. The CH star M22 III-106 found by McClure and Norris (1977) is one of these three stars. It does not show C_2 bands.

A full understanding of the complex and varied behavior exhibited by the C-, N-, and O-bearing molecules must be based on larger samples in a given globular cluster than the rather limited amount we have presented, as is described in the work of Carbon *et al.* (1982) and Smith and Norris (1982).

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